

Dr. Dobb's Journal of Software Tools

FOR THE PROFESSIONAL PROGRAMMER

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BRAINS:**
Artificial
Neural Networks

**Four Mac PROLOGS
Reviewed**

**Quick Expert
Systems**

**Educating
Programmers**

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C Version of Nroff
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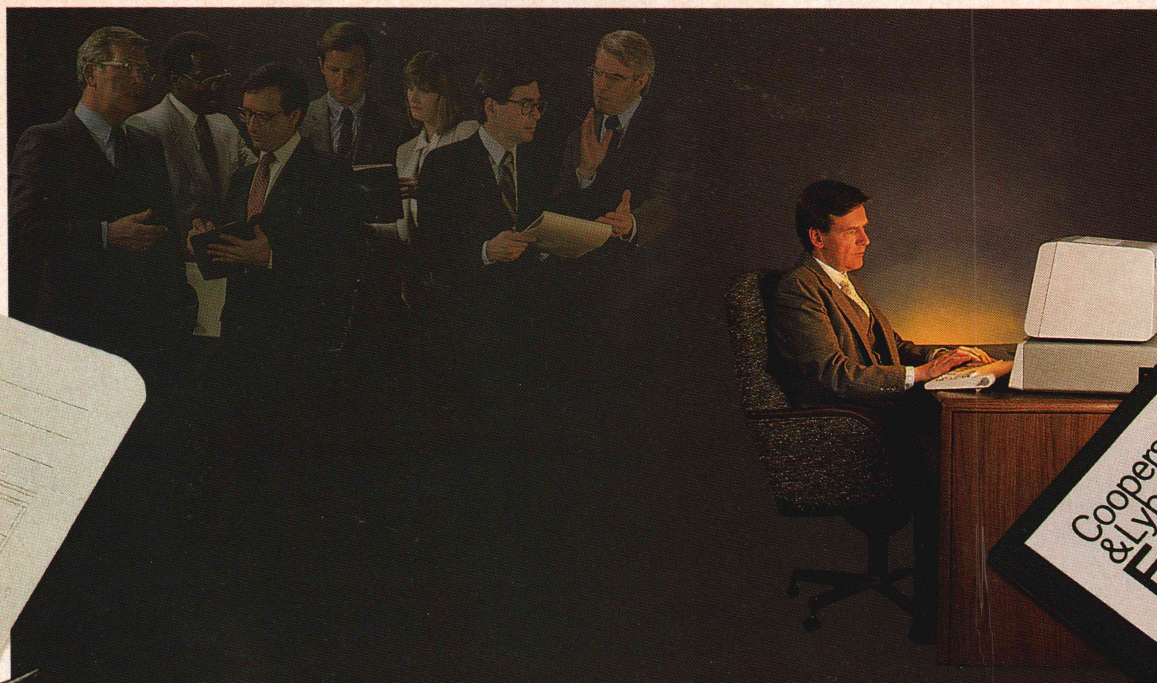
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by Robert Jay Brown

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by Richard W. Grigonis

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by Dan L. Pierson

Dan compares four PROLOG packages for the Mac and describes various dialects and features of the language.

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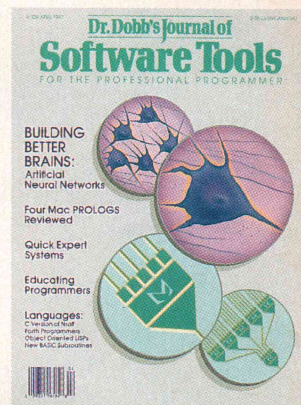
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Neural network programming takes the human nervous system as its model for program structure. Better brains? No, but brainlike programs, yes.

This Issue

Our third annual Artificial Intelligence issue reflects the state of AI today. LISP is now common; PROLOG, which virtually didn't exist on micros in 1985, is everywhere; expert systems are just tools; and the cutting edge of AI work is the learning problem.

Next Issue

For much of its short lifespan (about 30 years), computer music has been primarily an ivory-tower pursuit—if you wanted to do serious work in the field of computer-generated music you looked to the university research labs. Today, music algorithms also originate in the homes and workshops of people like you—people who program music applications on computers such as the Amiga, Atari ST and Macintosh.

Our May feature article includes a brief history of computers in music and focuses on some recent developments in MIDI programming, sampling, transient-oriented synthesis methods, and programs that compose and collaborate on original music. We'll also have an article about how to design a software-based music recorder using MIDI.

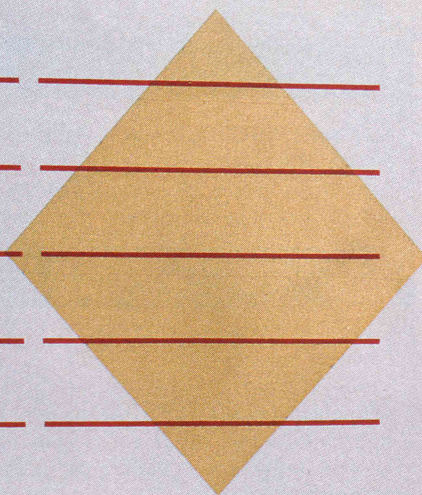


bandwidth topic



entry point

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EDITORIAL

Premise: Apple did several things right with the Mac 2.

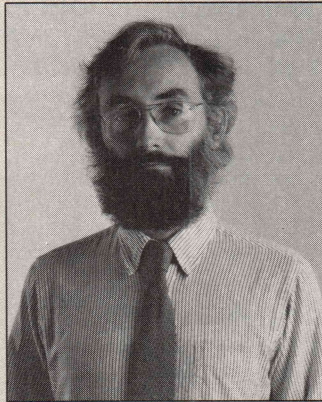
First, note that the new generation of 32-bit personal computers will beckon to the computer - literate masses, not just to programmers and power users. As Bob Enyart wrote in the January 27 issue of *PC Week*, "the less sophisticated a user is, the more dependent on very high-powered I/O and intelligent user interfaces he will be." Performance will sell well.

Second, note that performance in the next generation machines is rapidly going to become bus-bandwidth-bound, particularly if those less-sophisticated users are demanding such memory-hungry features as high-powered I/O. (Color graphics and voice synthesis were among the features that Enyart alluded to.)

Don't take my word for it: "In the next few years, the bus bandwidth to the main memory is going to be the issue which determines performance."—Hal Hardenbergh, *The Programmer's Journal*, September/October 1986.

And in terms of the 68020 specifically, "memory access time is one of the major obstacles to increasing the performance of the 68020 beyond what it already provides. Although it is possible to increase the clock frequency, the performance benefit, unless accompanied by decreased system access time, will be of diminished value."—Doug MacGregor and Jon Rubinstein, *IEEE Micro*, December 1985.

The disk drive data-transfer rate will also be critical. It's already possible to see the crippling effect of slow drives on fast processors. The Compaq Deskpro 386, which is just a fast micro after all, works as well as it does partly because it doesn't have a slow disk drive.



Commercial disk drive technology has been a five-megabit-per-second world, and five megs will bore a 386 or 68K unmercifully. Two faster drive interfaces currently getting attention are the SCSI (Small Computer Systems Interface) and the ESDI (Enhanced Small Disk Interface). SCSI will do up to 12 megabits; ESDI will do up to 24 megabits. SCSI is smart and cheap (a very-low cost do-it-yourself SCSI drive for the Mac was presented in the September 1985 issue of *DDJ*) and is becoming something of a standard.

In the light of this, consider Apple's choices of Nubus and an SCSI disk interface: an open-architecture, relatively low-cost, relatively high-bandwidth bus and a relatively low-cost, relatively high-bandwidth disk interface. Power, dare I say, to the people.

Of course, they left the CPU burdened with driving the screen. But I only said they did *some* things right.



Michael Swaine

Michael Swaine
editor-in-chief

Dr. Dobb's Journal of Software Tools

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RUNNING LIGHT

Like many of you, I'm a habitual hacker. But, also like most of you, I get burned out from time to time. When I joined *DDJ* last February, I was more than ready to stop programming for a while. I had just finished working on a large Macintosh project for a company that promptly went out of business. This kind of thing happens to freelance programmers once in a while, I fear. You put a lot of sweat, time, and craftsmanship into a project that ends up never seeing the light of day. And, often as not, you end up never seeing the paycheck for all that wasted effort either. These are the events that lead to programmer burnout, and I had it bad. When the opportunity to edit *DDJ* came along, I decided to take a break from programming and explore the world of magazine editing... frankly, I needed a change of pace; at *DDJ* I could talk and write about programming and get paid for it! An exciting possibility to be sure.



flurry of interest in such networks several years back, with the invention of various simple neural circuits that could be simulated relatively easily. But it amounted to little, partly because of limited hardware and partly because the models were not so-

phisticated enough. Now the field is heating up again, especially as we gain the power to simulate somewhat larger nets. As is typical of new fields, theories abound, and there's a lot of work to be done. We'd like to follow the developments closely; if you're working in the field, why not give us a call or send a letter?

In upcoming issues we'll be resurrecting the Professional Programmer department in our Programmer's Services section. The department will deal with various topics pertinent to those of you who are making your living as programmers—topics such as software copyright laws, products for producing firmware, and how to get your software published. We'll also have interviews with some well-known programmers and hear about their projects and their preferred tools for software development. If you have suggestions about what you'd like to see in the Pro Pro department, send a note to our assistant editor Levi Thomas. You can also reach Levi on CompuServe—ID number 76703.4060.

Who knows, we may even write something about how to avoid programmer burnout—if we can find someone who knows the trick to it...

It's been a heck of a lot of fun, folks. Stay tuned!

Nick Turner

Nick Turner
editor

In the meantime, this is our annual AI issue, with a feature article on a program that can be taught to recognize ASCII characters in graphic form. SILOAM represents the beginnings of the new field I mentioned recently—neural networks. There was a brief

ARCHIVES

The Expanding Mag

"Once again, we've published our largest issue ever! Our expansion is exciting; but at the same time, we are conscious that bigger is not always better. In this case, however, our increase in size will allow us options we haven't had in the past. With more editorial pages, we have the opportunity to present more variety each month, even when we run larger pieces, as we have in this issue and in the last."—*editorial, Reynold Wiggins, DDJ, August 1983.*

Predictions in AI

"The biggest revolution will come in terms of software. 'Actor-based' languages such as Smalltalk will allow programs to alter themselves to the user's wishes. If various present-day languages were embedded in such an actor language, ten strange new customized languages for specific purposes could be generated on demand, merely by the user having a 'conversation' with the larger host AI/actor program."—"5th Generation Computers," *Richard Grigonis, DDJ, December 1982.*

"So what have the Japanese selected as the lingua franca of their AI research? Not LISP, but PROLOG, an obscure language developed by the French and 'polished' by the British. PROLOG is the fundamental error in the otherwise sound Japanese Fifth Generation Project."—"And Still More Fifth Generation Computers," *Richard Grigonis, DDJ, August 1983.*

Ten Years Ago in DDJ

"We (the Professional Users Group) are not particularly interested in organizational clap-trap but rather in dissemination of both hard data and innovative fantasy, regarding technical features of small computer systems, both hardware and software. As an example of innovative fantasy, let me tell you about Dick Maus's project: to regard the game of 'life' as a subset of what Dick calls 'Superlife.' This algorithm will treat growth and decline phenomena in cell arrays. He sees applications for his simulation studies in such diverse fields as auto traffic flow, interaction of arrays of businesses in a given market, wave phenomena analysis, and nerve impulse transmission in neural tissue, just for starters."—*William J. Schenker, M.D., letter to DDJ, April 1977.*

... and a more-than-usually confused potpourri of interesting tidbits."—*last entry in table of contents, DDJ, April 1977.*

DR. DOBB'S JOURNAL of
COMPUTER
Calisthenics & Orthodontia
Running Light Without Overbyte

An Introduction to Wendin's Operating System Toolbox

This toolbox gives you a hands-on demonstration of how multitasking operating systems work.

Have you ever spent creative hours building things with Tinkertoys or an Erector set? Wendin's Operating System Toolbox gives you the same hands-on experience with operating system architecture that an Erector set gives you with mechanical engineering. You can use the toolbox as a development tool to write a custom operating system, or as a learning aid to discover how multitasking operating systems work. If you've ever wanted to build a better DOS, or see how big operating systems like VAX/VMS and UNIX really work, this product is for you.

The toolbox comes with complete source code, ready to compile. The roughly 15,000 lines of source code are librated to make the system fit on two floppy disks. About 85% of the system is written in C, and the remainder in assembly language for speed. The package comes with a 300+ page manual that describes how to build systems with the toolbox, and how the kernel works.

Kernel Architecture

The basic architecture of the kernel was designed around the VAX/VMS operating system. As shown in Figure 1, there are three major subsystems: the scheduler, memory manager, and I/O system. The kernel's subsystems communicate through common data structures which describe processes, memory usage, and devices.

Processes (or tasks) execute in 4 different access modes, depending on the level of access to system data structures they need. USER access mode, the least privileged, is where application programs execute, to keep other users' data protected.

"I heartily recommend the OST as an educational tool for experienced programmers of all types."

Jason Levitt
March Software Reviews for
Byte Magazine

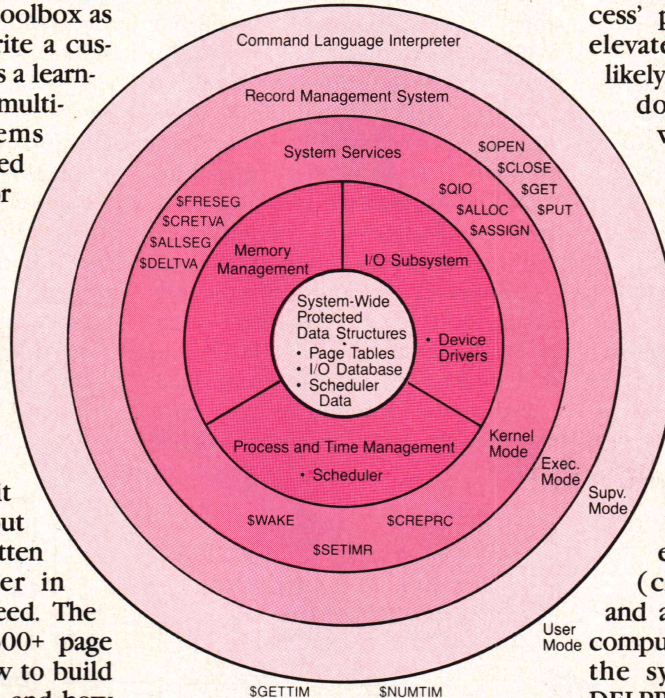


Figure 1. Layered architecture of Wendin's Operating System Toolbox.

The command language interpreter, or user interface, executes in SUPERVISOR mode, so that it can oversee the execution of user programs. The built-in Record Management System (RMS) executes in EXECUTIVE mode. Device drivers and process control services execute in KERNEL mode, the most privileged access mode. This allows other layers to make calls to a device specific layer, thereby making them device independent.

Scheduling

The toolbox schedules processes using the same sophisticated algorithm that VAX/VMS uses. Ready

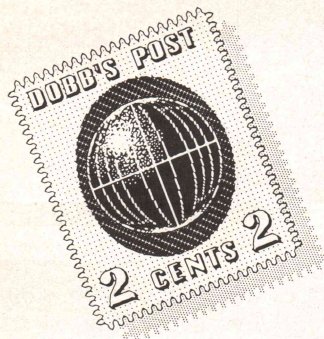
processes are collected in *computable queues* according to their current priority (0-31). Waiting processes are collected in other queues depending on their *state* (hibernating, suspended, waiting for I/O to complete, and so forth). A process' priority may be temporarily elevated so that it will be more likely to execute first when it is done waiting. For example, when a process is waiting for keyboard input, it remains in LEF (an I/O wait state) until the read has completed. When the read completes, the process priority is elevated to make response time quick.

Processes are moved by the scheduler from state to state according to the diagram shown in Figure 2. New processes enter the system via a CREPRC (create process) system call, and are immediately placed on a computable queue. Processes leave the system when deleted by a DELPRC (delete process) system call, which automatically makes the process current before deleting it. This means that there is only one path in or out of the system.

To select the next current process, the scheduler scans the computable queues for the highest priority process, and removes it from its queue. The process is then placed in the CUR state, and is executed. When a system event such as a timer tick or keypress occurs, the current process is placed back on a computable queue, and the event is serviced by some kernel component. After servicing the event, the scheduler finds another computable process to run.

When a process requests to be placed in a wait state such as

LETTERS



Software Gap

Dear DDJ,

I'm responding to the two "name withheld" letters in the January 1986 issue.

To the person whose managers have business backgrounds and don't understand software: I'd say turn-about is fair play. You know software and have strongly held standards—witness your letter and your *DDJ* subscription. You were interviewed for your current job and were deemed acceptable. In an interview, you have rights, too. Interview the person interviewing you. No need to be overly aggressive about it—there's always a line to walk—but see if you have common ground. Without that common ground, you're going to be unhappy. A good manager will recognize this, and you don't want to work for a bad one.

To the person concerned about sloppy code: You mentioned "it is sometimes difficult to determine when to stop coding and start stubbing." True enough, unless you have a plan. Let me suggest one. I like to add code to a running program. It's more enjoyable because the feedback is right there—it shows on the screen, the device runs, whatever. Debugging is simpler—you can see. Feedback is the crucial element in debugging.

So my suggestion: Write the main routine and enough I/O to get some feedback. Stub everything else. Get that running. So it's too easy/simple—

who cares? You have a place to stand, and the CPU is your lever. Now add code that makes the program do something simple. Then something else. Keep that feedback there. Otherwise the job can become work.

I think it's neat that I can go somewhere five days a week to have fun and actually get paid for it.

Joe Osgood
14930 Hartland St.
Van Nuys, CA 91405

More Searching for a Sine

Dear DDJ,

Richard A. Campbell's use of a Taylor's series approximation for the sine ["In Search of a Sine," December 1986] is the wrong approach to the problem. The question that should be asked is "What is the best finite polynomial approximation to a given function?" The answers have long been known and are to be found in the area of Chebyshev polynomials; Mainframe programmers have done a considerable amount of research on this topic. *Approximations for Digital Computers* by Cecil H. Hastings et al. (Princeton University Press, 1955) lists the sine function as well as a wide variety of common and esoteric

functions as part of a research study by the RAND Corp.

If you consider a polynomial approximation of three terms for the sine, the values of $C1 = 1.5706268$, $C2 = -0.6432292$, and $C3 = 0.0727102$ are derived from approximating theory, whereas Campbell's Taylor's series coefficients are $C1 = 1.570795$, $C2 = -0.645921$, and $C3 = 0.07948765$. For a polynomial approximation of four terms, the coefficients are the same for the approximating theory and the finite Taylor's series expansion.

Hopefully this will help Campbell and others in their investigations in this area. Too many implementations of computer languages ignore the vast amount of work that has gone before. The implementation of the sine and other well-known functions points this out.

I should also point out that Radio Shack offers a BASIC program that yields 15-digit accuracy on a 4K machine for a wide variety of functions (Level II Double-Precision Subroutine Program, catalog number 26-1704).

Douglas Ingalls
Ithaca College
Ithaca, New York 14850



Dear DDJ,

In December 1986 you ran an article in which Richard Campbell recounted his difficulty in locating a suitable approximation for the sine function.

Maybe I can make his day. I faced a similar problem a few years ago, and in my searches I came across a book that consists almost entirely of approximations—polynomial approximations, recursive approximations (!), infinite series, and infinite products—not to mention all the useful identities, integrals, and derivatives thereof. Would you believe a trig table with values for the sine and cosine functions to 23 significant places? (Great for checking up on that library approximation you're using!) And more.

I'm talking about the *Hand-*

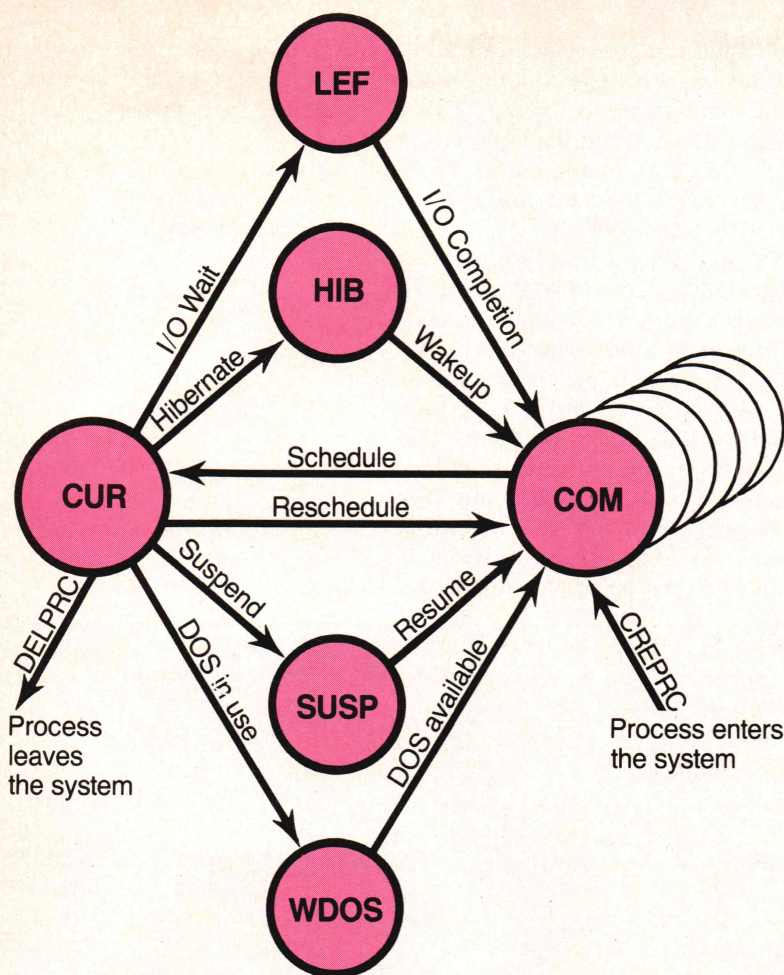


Figure 2. Scheduling paths and process states.

HIBernate or SUSPend, or if it requests a system resource that is not currently available such as a waited I/O or a DOS service, it is moved from the CUR state to the appropriate waiting queue (LEF, HIB, SUSP, or WDOS) until the resource becomes available. Once the resource is made available, the process is moved from its wait state to a computable queue, where it may be selected by the scheduler. In the case of HIB and SUSP, the process will wait until another process makes it computable with a WAKE or RESUME system call. A process can also wake itself up with a scheduled wakeup by calling the SCHDWK system call.

Memory management

The memory manager keeps track of available memory in 512-byte chunks called pages just like VAX/VMS. It uses a table of page descrip-

tors to keep track of which processes own the individual pages, and which access mode they were allocated in. Pages can be assigned to a specific process through the CRETVA (create virtual address) system call, and returned to the system with the DELTVA (delete virtual address) system call. Pages can also be allocated for global use and assigned a name so that processes can share data in memory. A process that wants to allocate memory to share with other processes calls the CREGBL (create global memory block) system call. Other processes can then access the global memory block by name using the ACCGBL (access global memory block) system service. When a global memory block is no longer needed, it may be returned to the system with a DELGBL (delete global memory block) system call.

Input/Output System

The I/O system handles all process requests for interaction with hardware and software devices. Hardware devices represent actual hardware, such as disks, terminals, and printers. Software devices include mailboxes (memory-resident data pipes) and the null device (bit bucket). I/O is supported through two levels of organization: device-specific (QIO) and device-independent (RMS). QIO device drivers deal directly with the physical properties of the device (for example, track size on a disk, or baud rate for a terminal). The RMS (Record Management System) level supports device-independent system calls which call the QIO level to do the work. This means that RMS isn't responsible for knowing about the specific characteristics of a device.

The User Interface

The final and most important component of an operating system built with the toolbox is the user interface. This C function is called by the kernel whenever it makes a new process. It is up to the designer to determine what a process should do. For example, some processes should read commands from their standard input device. Others should just run a program and leave the system. The user interface can be as simple as the MS-DOS interface or as sophisticated as the Macintosh windowing environment. As a development kit, it's powerful.

As a learning aid, it's fascinating. Wendin's Operating System Toolbox is an in-depth tour of an interesting field that simply can't be passed up for the price.

Minimum system requirements include an IBM PC/XT, AT, or true compatible with at least 256K running MS-DOS or PC-DOS.

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book of Mathematical Functions, edited by Milton Abramowitz and Irene A. Stegun, New York: Dover, 1965, originally published by the National Bureau of Standards of all people. After looking at dozens and dozens of mathematics and computer handbooks, searching in vain for an approximation of the gamma function, I finally came across this gem and had a rapturous religious experience on the spot. Now my copy resides next to Knuth, K & R, and other sacred writings of computer lore. I don't know how many times it has saved my derrière.

Your local college library almost certainly has a copy—go take a look, and see if it isn't everything I say it is.

William Zeidler
9 Pajaro Way
Salinas, CA 93901

Feedback

Dear DDJ,

You asked for input in the January issue, so here it is. First the complaint. At the bottom of page 16, you state: "you can move up from the 68008, which is roughly comparable to a fast Z80 in power." That is a gross misrepresentation—the 68008 is about four times faster than the 6809, and the 6809 runs rings around the Z80 (see the benchmarks published in *Interface Age*, April 1983). I agree that there have been several poor implementations of the 68008 (Hazelwood) that ran very slowly; however, a good hardware design (Peripheral Technology) will really fly.

In some instances the 68008 is faster than the 68000. A hard-disk driver where the sector buffer must be read and placed in memory is one such instance (see Example 1, right).

In the Right to Assemble column, the numbers project is super, and I am sure it will fill a large void in computer science literature. I wrote a 56-digit calculator for the 6809 in assembly language, and I could not find much help in any magazines or books. I had the same decision to make on the transcendental functions. The precision on the polynomial approximation was at the most 10 digits and I needed 56, so I had to use the series expansion. The arctan se-

ries would not converge around 1.5, so I devised a simple solution—I applied the half-angle formula three times and then multiplied the results by 8. This was so successful that I needed only 24 elements in the series for 56 digits of accuracy.

If I may brag a little, my CALC56 program calculates Pi (4*ATN(1)) in 14 seconds, accurate to 55 places. I needed four expansion series (sine, exponent of e, natural log, and arctan) in my calculator; all other functions could be derived from them. The source code is in 6809 assembly language and could easily be transported to the 68000. If you want to see this code, I would be willing to share. It would also be very interesting to see

if you have better algorithms than I have. If you need any constants calculated to high accuracy, just let me know.

Dan Farnsworth
3646 Lantana Rd.
Lantana, FL 33462-2299

DDJ

In 68000 code you would do this (A1 points to the destination.):

MOVE.W #255,D1	counter	8
LEA DCA,AO	DC addr	12
LOOP MOVE.B (AO),(A1)+	move byte	12
DBF D1,LOOP	loop	14
RTS		6656
		16
		6692 §

In the 68008 you make the hardware so that the disk controller addresses occupy 4 bytes consecutively:

MOVEQ1.L #63,D1	counter	8
LEA DCA,AO	DC addr	24
LOOP MOVE.L (AO),(A1)+	move long	
	word	40
DBF D1, LOOP	loop	26
RTS		4158
		32
		4222 §

If memory is available you can do this:

LEA DCA, AO	DC addr	24
MOVE.L (AO),(A1)+	move long	40
MOVE.L (AO),(A1)+	move long	40
!		
!		
!		
MOVE.L (AO),(A1)+	64 2 byte instructions	40
		2616 ~

Example 1: Sometimes the 68008 is faster than the 68000.

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*The benchmark procedure was adapted from "Benchmarking Database Systems: A Systematic Approach" by Bitton, DeWitt and Turbyfill, December 1983.



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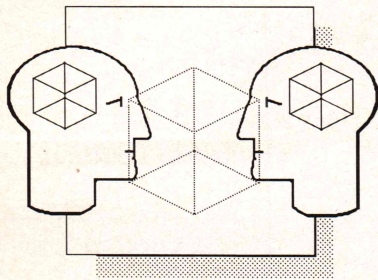
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VIEWPOINT



Education and Programming

There is a popular misconception (popular among educators and laymen alike) that programming and mathematics are somehow related. As a consequence an undue amount of math is forced down the gullets of unwilling undergraduates in every computer science program in the country. I feel that not only is this needless torture but it also can be counterproductive.

To my mind, a good, traditional, liberal-arts education—one that includes a little math but that also includes things such as English composition, history, and Latin—is better preparation for a programming career than a math- or science-oriented education. Many of the worst programs I've seen have been written by mathematicians and physicists and some of the best have been written by people with degrees in English and Russian Literature. How is this possible if programming is as grounded in math as some would

by Allen Holub

have us believe? More to the point, many potentially excellent programmers are forced out of computer science programs every year because they don't have an aptitude for mathematics. The other side of the problem is that many programmers who do graduate are not fully in touch with the world around them because of the unwarranted dominance of technical training to the detriment of nontechnical but equally valuable kinds of knowledge.

Before continuing, I need to clarify

my terms. There's a difference between *programming* and *computer science*, between the writing of programs and the study of them. Computer science has a great deal to do with mathematics; programming does not. I'm also differentiating between engineering and programming. You obviously need to understand mathematics to write a program that does mathematical things.

On the other hand, the creation of a computer program, regardless of the function of that program, is a different process from designing the math-related algorithms that the program implements. In any event, most programs don't implement mathematical algorithms, and if they do, the algorithms are often designed by someone other than the programmer. How much calculus is there in a word processor or a database application?

The skills you need to solve a math problem are virtually useless when it comes to writing a program. At the undergraduate level, at least, you solve a math problem by repetitively applying a set of memorized rules to an equation until one or more of those rules does something useful. If you tried to write a program this way, you'd never get beyond the *main()* module. On the other hand, the process of writing an essay is almost identical to that of writing a program. You start both with an outline of some sort (what is a structure chart or a Warnier-Orr diagram if not an outline?), you have to organize both in the same way (a topic paragraph is a *main()* subroutine, the routines that *main()* calls are sections in the essay, and so forth), and the stepwise refinement of a program mirrors the development of an idea within an essay.

The study of a language, especially a classical language such as Latin, is also useful to programmers. It's not the Latin itself that's important—though a knowledge of Latin certainly does help improve your English—but rather it's the tools that you need to learn Latin that are important. You are really teaching yourself how to understand a large and complex system, and once you've understood

how to learn the language, you can apply these same techniques to any complex system, such as a computer program.

These problems can be solved, to some extent, by a restructuring of the educational process. I'm arguing here, not for the restructuring of computer science programs as such, but rather for the creation of a new academic discipline entirely—one that's concerned primarily with programming. A little math is obviously required—basic algebra, a little Boolean and linear algebra, some set theory, and (a very little) calculus are all that's needed, however. These topics could be covered quite adequately in a well-designed one-semester course, and as I said earlier, a little math is just as much a part of a liberal-arts education as is English. If students were required to take a full year of English composition rather than calculus, not only would we have better-written programs, but we'd have readable documentation for them as well. The study of computer science as such could then be moved to the graduate level, as is fitting for an essentially academic discipline. A good parallel is the way that you'd earn a medical degree—a bachelor's degree in a related but more general field is required before you can enter a graduate-level M.D. program. Similarly, a degree in programming would be a prerequisite for a degree in computer science.

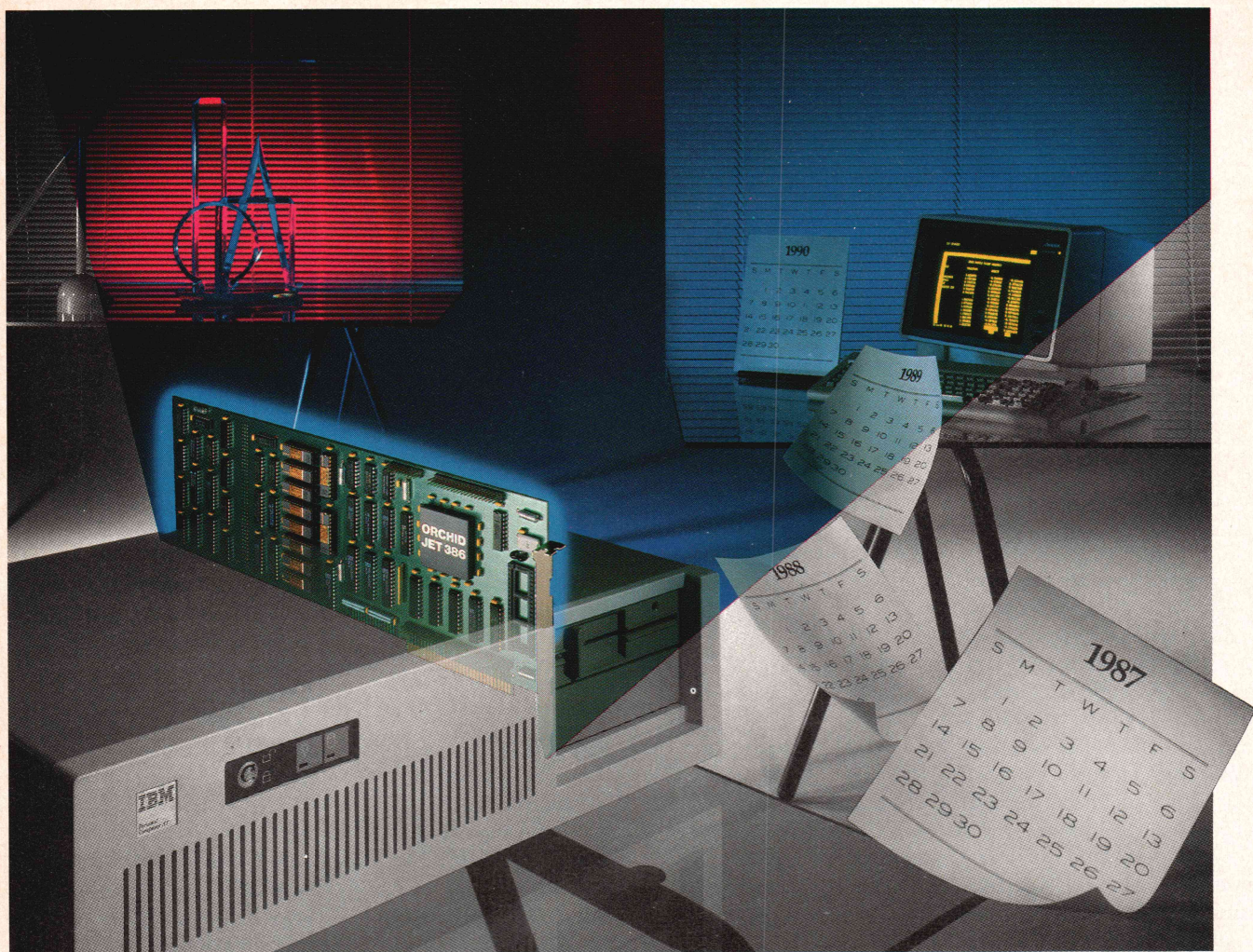
In the long run this sort of restructuring would give us both better programmers and better computer scientists.

DDJ

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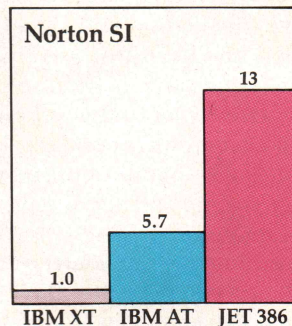
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Circle Reader Inquiry Number 130

An Artificial Neural Network Experiment

by Robert Jay Brown

This article describes an experimental computer program that could serve as one component of a computer vision system. The program simulates an artificial neural network and acts as a learning machine. It's implemented as a committee network of threshold logic units that functions as a trainable pattern recognizer for visual images composed of a rectangular array of pixels. Each pixel contains a single number representing the gray-scale value of that region of the field of view.

A robot vision system consists of many components:

- image capture, in which the image is converted from light or other radiation to an analog electrical signal
- image digitization and signal processing, in which the image is divided into a set of picture elements, or pixels, each of which is assigned a value representing the brightness and/or color of that part of the image
- region, edge, and boundary detection, in which the distinct visual elements of the image are separated
- image scaling and alignment, in which the digitized image is rotated, translated, and otherwise transformed to place it into some standard position and size
- image recognition, in which the preprocessed image is submitted to a pattern recognition algorithm to allow the machine to recognize what the image represents.

This article is about image recognition.

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***This program
acts as
a
learning machine.***

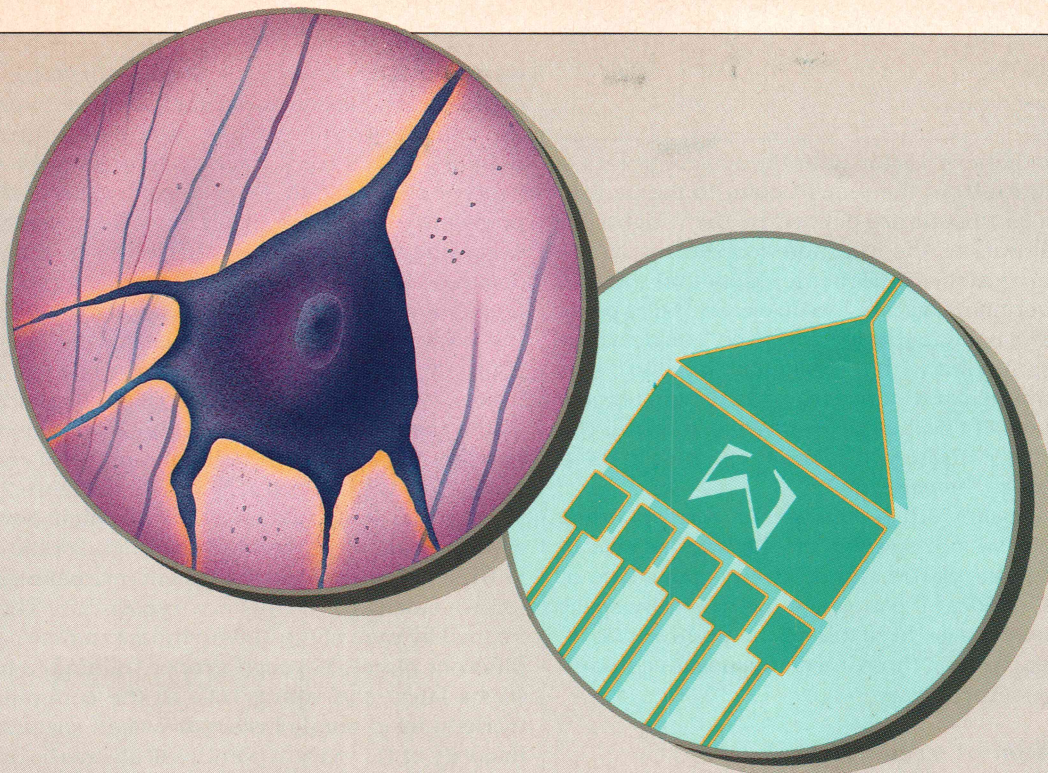
Neurophysiology

SILOAM (simple image learning on adaptive machinery) operates by modeling one possible organization of the actual neural structure of the brain on a computer. Consider a single nerve cell (see Figure 1, page 18). During

World War II, a physiologist and a mathematician worked together to try to create a model of the brain based on anatomical and physiological experimental findings. The team of McCulloch and Pitts started by modeling the single nerve cell, or neuron. Their model is known today as the McCulloch-Pitts neuron and is depicted in Figure 2, page 18.

Microscopic studies reveal that the nerve cell is composed of a cell body, or cyton; many input fibers, or dendrites; and a single output fiber, or axon, which branches to send signals to the dendrites of other nerve cells. Physiological studies in which scientists selectively stimulate sets of dendrites while observing the axon yield the following result: some dendrites tend to cause the neuron to produce an output (the neuron "fires"), and other dendrites tend to prevent the neuron from firing. The dendrites that encourage firing are called "excitatory" inputs, and those that discourage firing are called "inhibitory" inputs.

The cell either fires or does not fire. There is no specific tie between which inhibitory input cancels an excitatory input. Each input has a "weighting factor" associated with it: excitatory inputs have a positive weight, and inhibitory inputs have a negative weight. The neuron combines all these inputs (probably within the cyton) to produce the output. Thus it appears that the neuron adds up all the weights associated with inputs that are stimulated, and if the result exceeds a certain threshold, then the neuron fires.



Threshold Logic

This model of a neuron (Figure 3, page 18) is called a threshold logic unit (TLU). It is not difficult to construct a TLU out of readily available hardware components: a Schmidt trigger connected in series after an operational amplifier wired to operate as an analog summer will suffice (see Figure 4, page 19). The weights are the gains determined by the proportionality factors of the scaling resistors at the plus or minus inputs to the op-amp. Adjustable weights can be realized by using potentiometers with the wiper connected to the stimulus input, with one end of the resistance element connected to the plus input of the op-amp and the other end connected to the minus input. I chose to simulate the operation of a TLU with software. It's cheaper, and as you shall see, it allows the program to adjust its own weighting factors, which is necessary if the TLU is to be trained automatically rather than "tweaked" into alignment by a skilled technician.

The TLU is the physical embodiment of a linear equation formed by setting an inner product, or metric (measure of distance), to 0. The solution set for the equation thus formed defines a cleaving plane that acts as the boundary between two half-spaces in the weight space of all possible weight sets that could make up the weights for the input of a TLU. The cleaving planes, being the solution to a homogeneous linear equation, must pass through the origin. When the equality is changed to an inequality, the sign of the inequality indicates on which side of the cleaving plane the weight point lies.

SILOAM contains many TLUs. Each has as many inputs as there are pixels in the graphical array that is being examined by the network. In addition, each TLU has an additional input that is always excited. This extra input provides a "reference point", or "bias" (analogous to the DC component of a Fourier series), to set the threshold that determines the firing point of the TLU. This input is necessary to homogenize the linear equation formed by

the inner product used to compute the metric. Without it, an input of all 0s would degenerate and the training algorithm would fail to converge.

Pattern-Space Geometry

The task of computing the output of a TLU is performed by the vector operation of taking the "dot product" of the stimulus vector and the weight vector associated with the TLU. The sign of the result determines the output: a positive sign means the nerve has fired; a negative sign means it hasn't. Each weight vector can be interpreted as a point in hyperspace, or weight space. If you look at the dot product formed between the input pattern vector and the TLU weight vector, you see that, if the elements of the pattern vector are viewed as constants and the weight vector elements are viewed as variables, then if the dot product is set equal to 0, this dot product forms a linear homogeneous equation. The situation in 3-space is:

$$ax + by + cz = 0$$

A, b, and c are the components of the weight vector, and x, y, and z are the components of the pattern to be recognized. Remember that z is set to a constant value of 1. The solution set defines a plane that passes through the origin (see Figure 5, page 19). The plane forms a pattern surface that cleaves weight space into two half-spaces: this places one set of possible TLU weights on one side of the pattern plane and one set on the other side. Any given weight point will be on either the negative or the positive side of the pattern plane. (The two's complement arithmetic of the computer makes it convenient to consider a point lying on the plane itself to be on the positive side of the plane.)

The absolute value of the dot product is proportional to the perpendicular distance from the weight point to the pattern plane. Thus a given pattern hyperplane divides weight hyperspace into two half-hyperspaces. The dot

product of the pattern vector with the weight point returns the distance from the weight point to the pattern plane. The weight points are defined by the weights for each of the inputs to the TLU; the coordinates of the weight point are just the values of the weights for the TLU.

By this convention, you can visualize each TLU as being represented by a point in this weight space. The dot product of the weight point with the augmented pattern vector is the perpendicular distance from the weight point to the pattern plane. If this quantity is positive, then the TLU "recognizes" the pattern; if it is negative, then the TLU does not recognize the pattern.

The TLU is a pattern dichotomizer: its corresponding weight point in weight space is on the positive side of some pattern hyperplanes and on the negative side of others. Thus it divides all pattern planes in weight space into two classes, or sets: those it is on the positive side of, which it recognizes, and those it is on the negative side of, which it does not recognize.

Artificial Neural Networks

Now, how about more difficult cases, in which a simple

linear function cannot separate the categories? I will first explore a yes/no decision from a single network and will use one possible network of TLUs, called the committee network (see Figure 6, page 19). The committee network is a type of layered machine. A committee of TLUs is composed of an odd number of TLUs, each presented with the same input pattern vector. Each TLU in the committee decides whether the pattern is one that it recognizes, and it casts a vote accordingly. A chairman TLU then counts the votes. The chairman's inputs are the outputs of the committee members. Its weights are fixed at 1 for all its inputs, so it simply functions as a vote counter for the rest of the committee. By training multiple networks independently, you can increase the number of recognizable classes to any power of 2, as shown in Figure 7, page 20.

I have developed a democratic machine: how can such a thing work? I'll now show how a democratic committee with a majority-rule voting system can make a substantial improvement to my pattern recognizer. The divisions formed by each of the TLUs in the committee can occur at different places. Through proper training (which I'll describe later), the voting TLUs in the committee can be made to form point clusters in weight space such that a majority of TLU weight points will always be on the proper side of every presented pattern hyperplane. Thus you

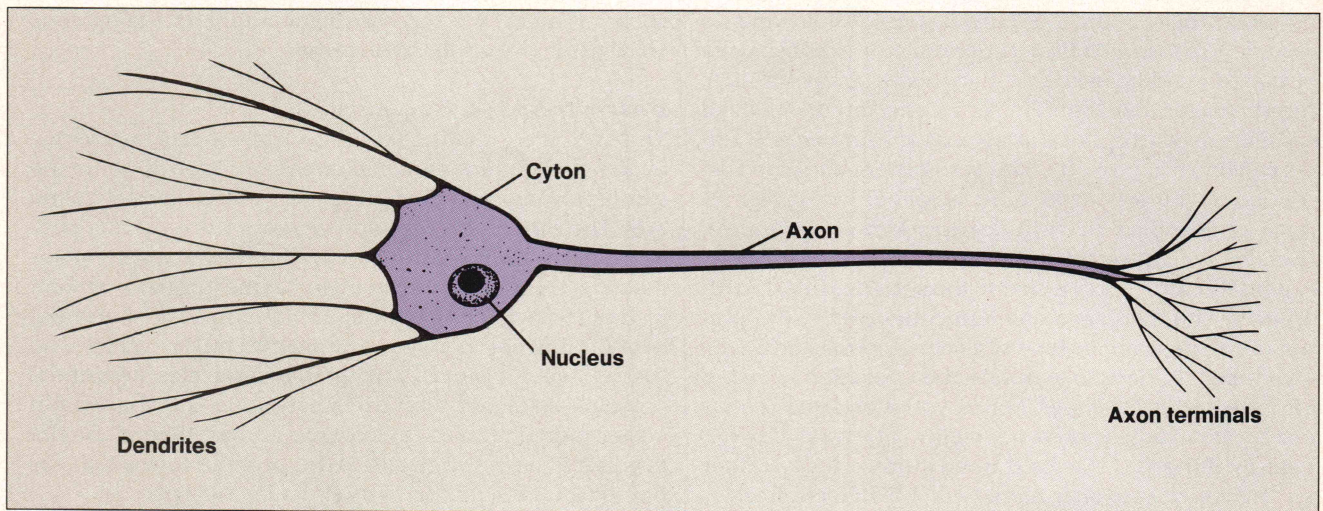


Figure 1: A nerve cell, or neuron

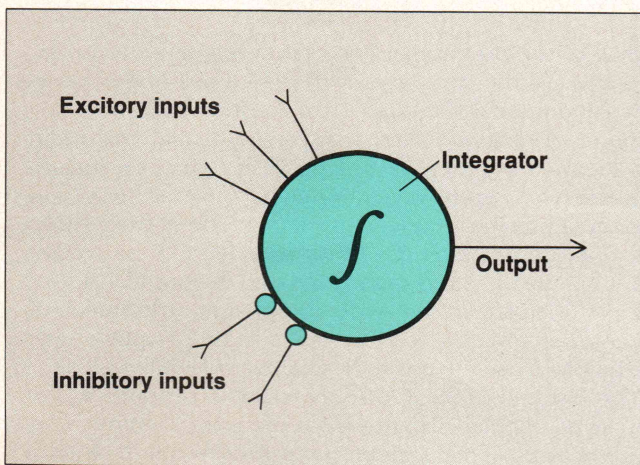


Figure 2: McCulloch-Pitts neuron

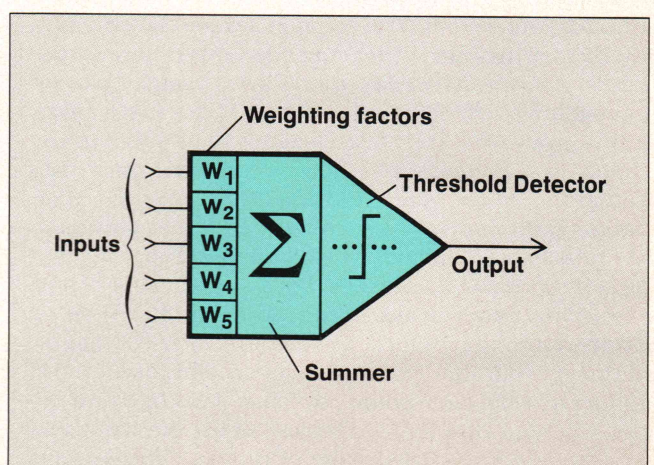


Figure 3: The threshold logic unit

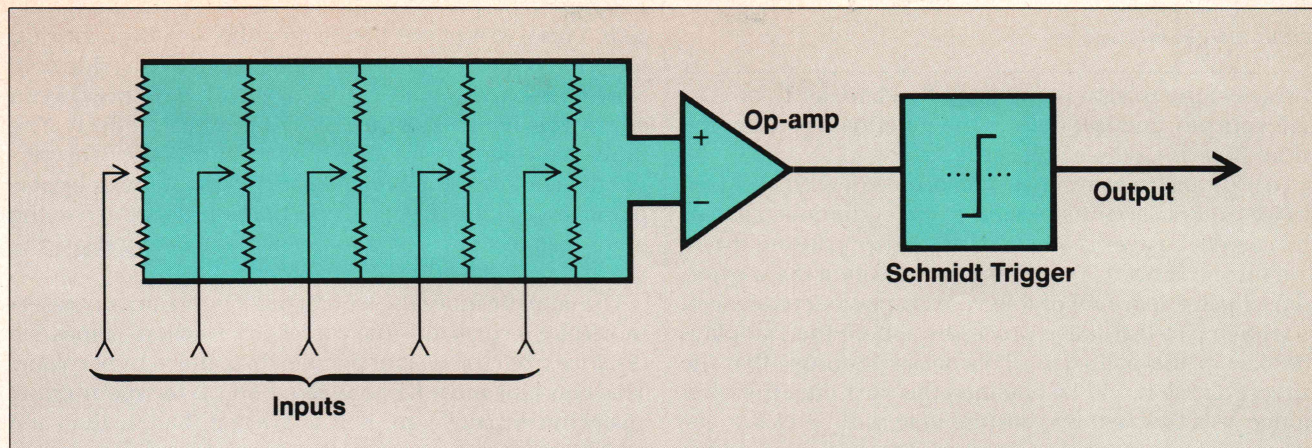


Figure 4: Simplified hardware implementation of a threshold logic unit with adjustable weights

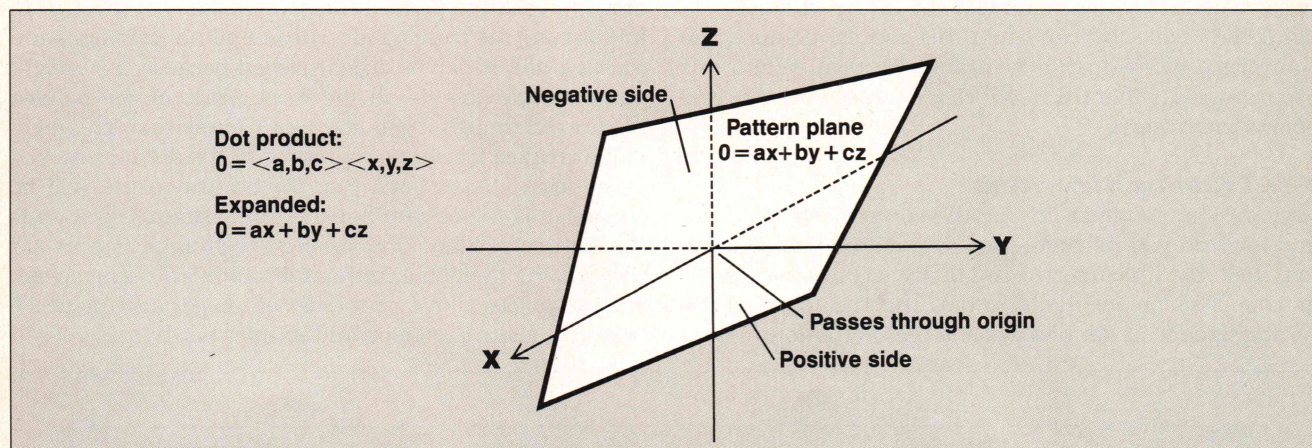


Figure 5: The pattern plane as a linear homogenous equation derived from a dot product

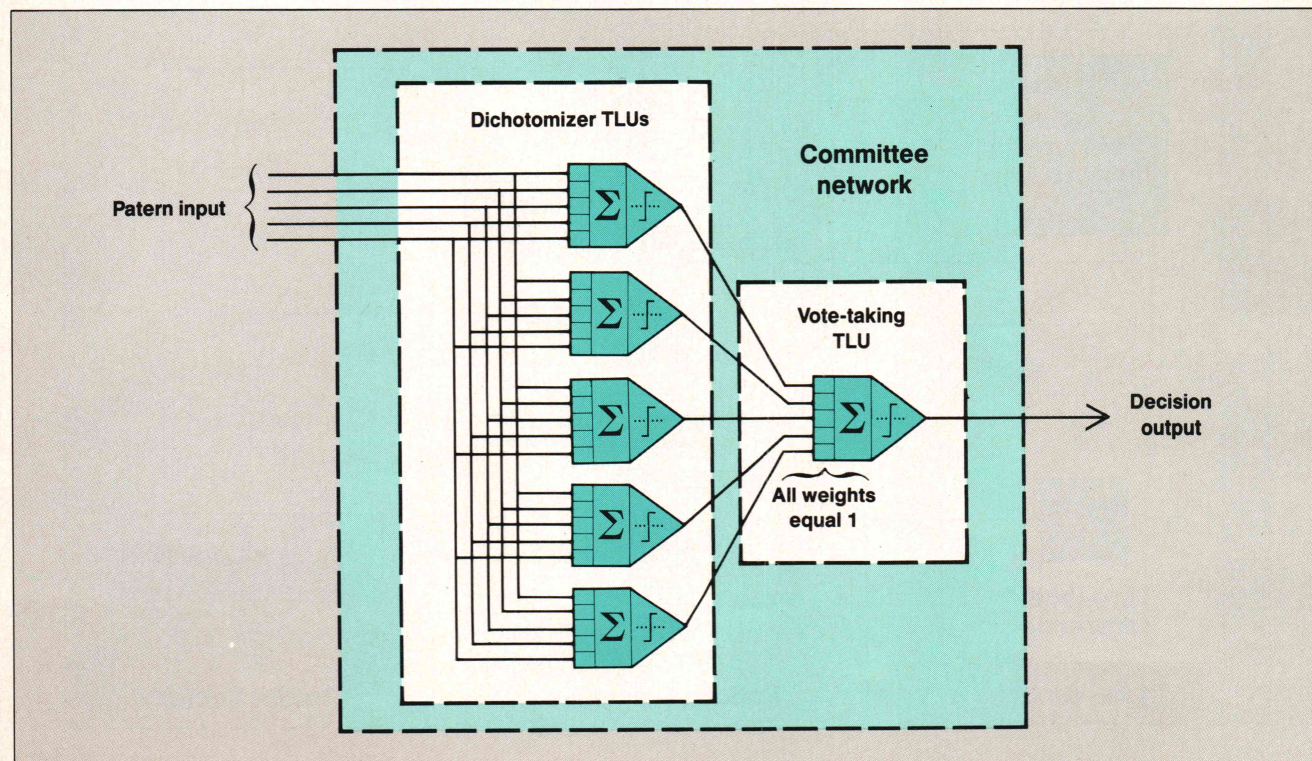


Figure 6: A committee network of threshold logic units

can select the weight points such that a majority of TLUs will vote yes, and this defines the set of patterns that the committee as a whole will recognize.

To train such a committee, you present it with a pattern vector and observe the result. If the committee returns the correct answer, you present another pattern; if not, you must correct it. You do this by adjusting the weights to produce a more favorable vote (somewhat equivalent to lobbying in legislative processes, where the TLU plays the part of the politician). This does not ensure that the correct decision will be obtained the next time the committee sees this pattern, but the vote will be closer. Because you insist on an odd number of TLUs in a committee (exclusive of the chairman), you can never have a tie. What you do is convert one TLU at a time to a more "enlightened" view. By repeating this process enough, the committee will return a favorable decision. When this occurs, you say that the network has been trained to recognize the pattern.

The Training Algorithm

How do you go about finding the correct TLU to adjust, and how do you perform the adjustment? You pick the TLU that voted incorrectly and that was the least sure of its vote. This means that you pick the TLU that had the wrong sign for its dot product and that had a dot-product

magnitude that was the least of all TLUs with the wrong sign. This corresponds to selecting the weight point closest to the pattern hyperplane and on the wrong side of it. Now you know which TLU to work on, but how do you adjust the weights to produce the desired effect? You move the weight point for the selected TLU along the perpendicular from the weight point to the pattern hyperplane toward the pattern hyperplane and through to the other side of the pattern hyperplane, thereby changing the TLU's classification of the pattern.

You actually move the weight point by an amount determined by a constant—the correction fraction—times the distance from the weight point to the pattern hyperplane. This constant must lie between 1 and 2 for the training algorithm to converge. If it is greater than 1, then the weight point will move to the other side of the pattern hyperplane; if it is less than 1, then the weight point will move toward the pattern hyperplane but not through it. In this case, the training algorithm will not converge and training will never be accomplished because the weight point will always be on the wrong side of the pattern plane even though it gets constantly closer to it. This technique is called fractional correction. If the distance moved is the least integer such that the pattern plane will be crossed, this choice results in a training strategy known as absolute correction. The simplest technique is constant correction, in which a constant distance is always moved. Such strategies allow for the use of integer arithmetic resulting in faster execution and simpler hardware.

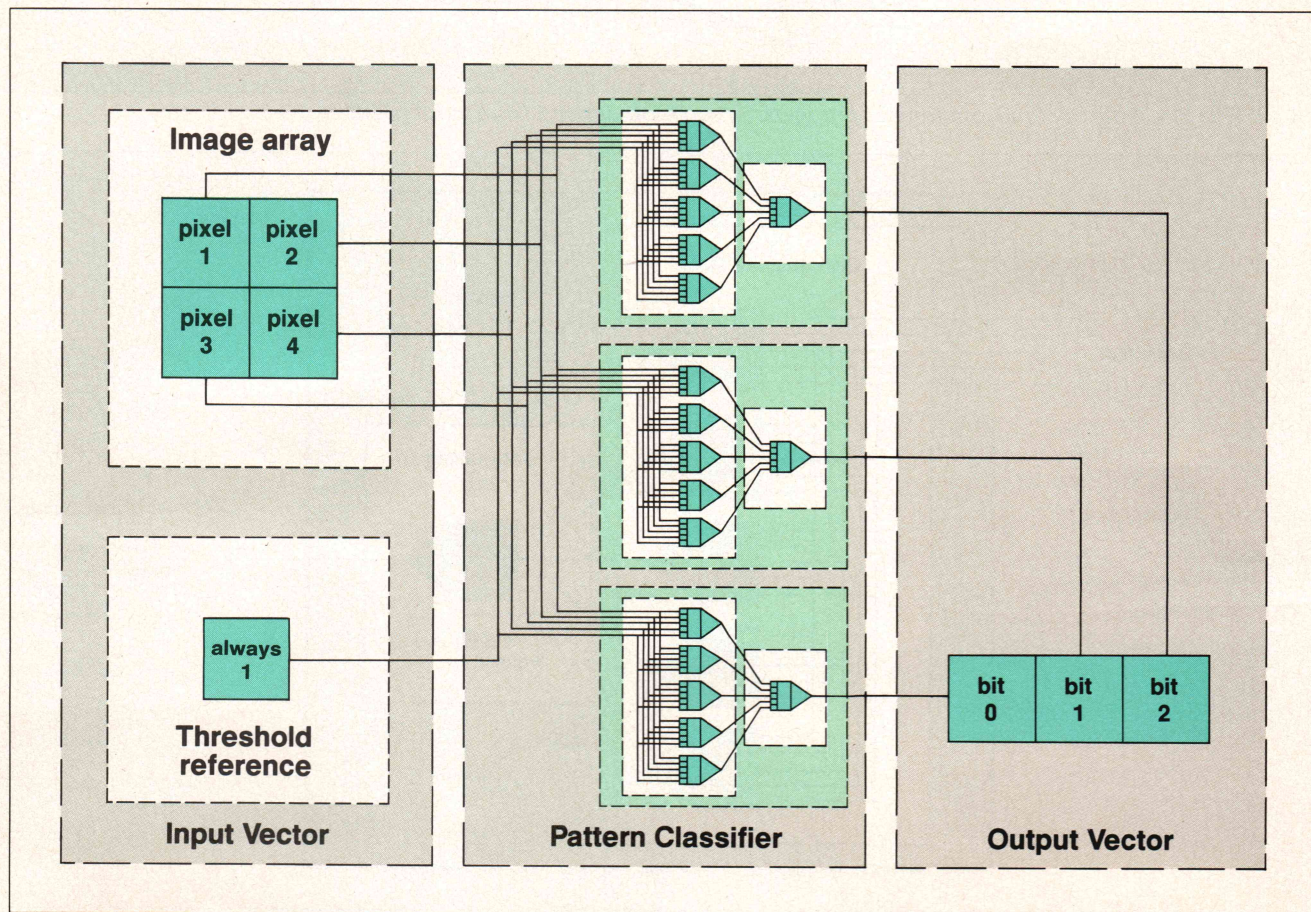


Figure 7: An image learning system to classify 2^n patterns

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Fixed-increment correction with binary images using 8-bit signed integer weights lends itself to cheap parallelism. A separate Intel 80C51 microcomputer on a chip could be used for each TLU, taking weight points out of an array in on-board ROM. Using six committees of seven voting TLUs each, plus a single 80C51 to count all the votes and act as central control, results in $6 \times 7 + 1 = 43$ 80C51 processor chips. A system such as this should be able to perform real-time optical text scanning of printed literature. Using surface-mount or hybrid packaging methods, the device might be as portable as a Walkman. A speech synthesizer could serve as an output device, receiving ASCII text from the pattern recognizer. Voilà!—a reading device for the visually handicapped. To this end, I have examined the performance of an 8-bit integer network with fixed-increment correction with encouraging results. The TMS-320C25 digital signal processor from Texas Instruments may prove less expensive than the 80C51 array. Although the 320 is more expensive, it is much faster than the 80C51, and the overall system cost may be less.

The Experiment

There are actually three versions of SILOAM—a floating-point version, a 16-bit integer version, and an 8-bit integer version (see Listing One, page 56). The symbol *ELTYPE* is defined on the compiler invocation line and determines the type definition for an element of a weight point vector. You select the pattern presentation order for training with the *-o* option and select initial conditions for the weight points with the *-r* option. The correction method is selected with *-a*, *-i*, and *-f* options, which specify absolute, fixed increment, or fractional correction, respectively. You select the level of detail for logging with the *-l* option: *-l0* displays only final results; *-l3* displays the most detail.

I ran the program on a small pattern file, representing a

0. 1. 0. 0.	0. 1. 1. 0.	1. 1. 1. 0.	1. 0. 0. 0.
1. 1. 0. 0.	1. 0. 0. 1.	0. 0. 0. 1.	1. 0. 1. 0.
0. 1. 0. 0.	0. 0. 1. 0.	0. 1. 1. 0.	1. 1. 1. 1.
0. 1. 0. 0.	0. 1. 0. 0.	0. 0. 0. 1.	0. 0. 1. 0.
1. 1. 1. 0.	1. 1. 1. 1.	1. 1. 1. 0.	0. 0. 1. 0.
1	2	3	4
1. 1. 1. 1.	0. 1. 1. 1.	1. 1. 1. 1.	0. 1. 1. 0.
1. 0. 0. 0.	1. 0. 0. 0.	1. 0. 0. 1.	1. 0. 0. 1.
1. 1. 1. 0.	1. 1. 1. 0.	0. 0. 1. 0.	0. 1. 1. 0.
0. 0. 0. 1.	1. 0. 0. 1.	0. 1. 0. 0.	1. 0. 0. 1.
1. 1. 1. 0.	0. 1. 1. 0.	0. 1. 0. 0.	0. 1. 1. 0.
5	6	7	8
0. 1. 1. 0.	0. 1. 1. 0.		
1. 0. 0. 1.	1. 0. 0. 1.		
0. 1. 1. 1.	1. 0. 0. 1.		
0. 0. 0. 1.	1. 0. 0. 1.		
1. 1. 1. 0.	0. 1. 1. 0.		
9	10		

Table 1: Binary images of numerals

binary image of each of the numerals 0–9 (Table 1, below). It has also successfully learned the entire uppercase alphabet. The alphabet pattern file was generated by rasterizing characters from the Hershey character database of the National Bureau of Standards. The entire ASCII character set was generated in this fashion as a high-resolution dot-matrix raster and was taught to SILOAM. The output produced by a run of the program with the high-resolution sample character set is shown in Example 1, below.

It is interesting that a network of only one TLU per committee could learn all of the binary images of the character sets. When this is the case, the pattern set is said to be "linearly separable." A pattern file of random analog pixel values was generated, comprising 100 images. In this case, a single TLU could not learn the pattern set—three TLUs were required, and different training methods produced radically different results. Fixed increment performed quite poorly, absolute correction did somewhat better, but fractional correction did the best. Values of the correction fraction closer to 2 seemed to perform better and resulted in faster convergence. In fact, convergence was even achieved with values greater than 2, although when they got up to about 2.5, convergence failed.

Limitations

SILOAM can actually get confused and forget things it has already learned in the process of trying to learn new things. In *Learning Machines*, Nilsson shows, however, that the training procedure will converge to the desired result, given that you choose a suitable distance to move the weight point and that you do not exceed the capacity of the machine (related to the number of TLUs per committee and the number of patterns to be recognized). This result is known as the Fundamental Training Theorem, or the Perceptron Convergence Theorem.

Despite the impressive performance of this simple network, it has some serious theoretical shortcomings—for example, it cannot learn a simple exclusive-OR function.

```

Invoked By: ascii -i1 -t1
element type is int

initializing

mean of the radii: 31.749012
standard deviation: 0.001284

training completed in 5771 seconds.

number of committees: 7
number of tlus total: 7
number of elements: 7063
number of connections: 6302

number of passes thru file: 78
number of patterns in file: 87
number of mis-recognitions: 1190
number of tlu adjustments: 1190
maximum element magnitude: 49.000000

mean of the radii: 83.3047640
standard deviation: 0.582814

```

Example 1: Output of SILOAM with high-resolution character set

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```
04-08-86 13:45:44 dem3.prg
Sun 04-08-86 13:45:47

1 PUBLIC value, val1, val2, val3
2 USE VALUE, INDEX, DATE
3 date:=cdate("12/30/85")
4 DO WHILE date < cdate("01/01/86")
5   date:=date+1
6   READ any "Enter date: " get da
7   READ
8   DO LOOP
9   value = 0.00
10  val1 = 0.00
11  val2 = 0.00
12  val3 = 0.00
13  DO WHILE NOT
14  IF Present in date1
15  DO CASE
16  CASE Selector = "1"
17  DO PROC1
18  CASE Selector = "2"
19  IF Quan > 0.00
20  value = value + Quan
21  val1 = val1 + Quan
22  CASE Selector = "3"
23  IF Quan < 0.00
24  value = value - Quan
25  val2 = val2 + Quan
26  CASE Selector = "4"
27  value = value + Quan
28  val3 = val3 + Quan
29  CASE Selector = "5"
30  DO PROC2
31  DO CASE
32  CASE Selector = "1"
33  IF value > 0
34  IF value < 0
35  DO CLEARUP
36  CLEAR
37  CLEAR ALL
```

dBASE

```
1 source ()
2 while (lar < nres && ares[lar][0] == c)
3 {
4   if ((d = ares[lar][1]) == 0)
5   {
6     p = &(ares[lar][1]);
7     while (d = *p)
8     {
9       loop++;
10      lar++;
11    }
12  }
13 }
14 }
15 }
16 }
```

C

Before

```
150 FOR INDEX = 1 TO 100
160 IF TB(INDEX) = 0 THEN X = 5
170 C = 50: WHILE K <= 1000: TB(K) = 0: K = K + X: WEND
180 GOSUB 2000
190 XT(C) = X: T2(C) = K
200 NEXT INDEX
```

```
150 FOR INDEX = 1 TO 100
160 IF TB(INDEX) = 0 THEN X = 5
170 C = 50
180 WHILE K <= 1000
190 TB(K) = 0
200 T = K + X
210 WEND
220 GOSUB 2000
230 XT(C) = X
240 T2(C) = K
250 C = C + 1
260 NEXT INDEX
```

BASIC

After

Wed 12-31-86 07:22:03 INDEX (Cross Ref)				
all identifiers				
inrecord	4.191	9=396	19.825	19=826
	21.889	22.922	22.953	23=978
	23.990			
ins	53.2293	53=2309	53=2319	53.2325
	54.2331	54.2332	54.2336	54=2346
	54.2354	54.2364	54.2365	54.2366
intext	4.193	9=395	43.1796	43.1815
	43=1820	45=1902		

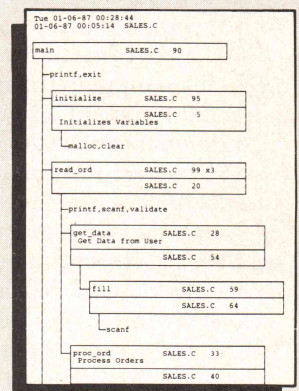
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This deficiency can be shown with a geometric proof. Because there are two variables input to an XOR, a 2×1 input pattern is needed. This results in three dimensions for the pattern space. Because there are four combinations of the inputs, there are four pattern planes. All four planes pass through the origin. If you imagine a sphere about the origin, these four planes intersect the sphere in four great circles and these four circles each intersect each other. If you place the south pole of the sphere on the origin of a 2-D graph and project the surface of the sphere onto the plane (as in a polar projection of the globe), four intersecting circles result—one centered in each quadrant of the plane. Their common intersection is around the origin of the graph. If you count the number of distinct regions into which these circles divide the plane, you get 14, but there are 16 possible combinations of accepting and rejecting 4 distinct patterns composed of 2 independent variables. The exclusive-OR and the exclusive-NOR, or equivalence relation, are these missing regions. You can use a similar argument in higher dimensions to show that all such networks are likewise deficient in not being able to learn all possible pattern sets with which they could be confronted.

In *Parallel Distributed Processing*, Rumelhart et al. show, however, that other network topologies, neural activation functions, and training algorithms—especially the gradient-descent training method—are capable of producing all possible Boolean switching functions. I highly recommend their book for anyone interested in pursuing the study of artificial neural networks in depth.

Topics for Further Investigation

One idea that needs to be explored is recognizing patterns over time—that is, sequences of patterns. One idea might be to incorporate some sort of feedback into the network to provide a memory capability. The output bit vector could be concatenated with the pattern input vector to provide an input to the network that was a function not only of the current input but also of the previous output.

Additional exploration could be done with nonbinary pattern elements. Remember that the recognition process does not require the elements of the pattern vector to be 1s and 0s; any real values will still satisfy the vector geometrical constraints and should be recognizable with essentially the same algorithm.

Geoffrey Hinton discussed some of his work with artificial neural networks at the AAAI-86 conference in Philadelphia last August (see bibliography). He showed how a real-valued, differentiable activation function could be trained by the method of gradient backflow to form its own independently developed internal abstractions. His experiment involved learning two similar family trees. The network formed, on its own and without being taught explicitly by the examples, the abstract concepts of generation and various family relations. It was also able to generalize its experience to determine the relations between individuals it had not been previously introduced to. It got better than three out of four new problems correct. Hinton showed that a statistical correlating

recognizer would fail this test and that true generalization of induced abstractions was being performed.

Neurophysiology Revisited

What can you learn about the natural mind based on a model neural network? Psychiatrists treat mental illness with drugs, such as phenothiazines and lithium, and with electroshock therapy. Electroshock therapy is assumed to destroy connections, thereby altering weights by setting them to zero. Phenothiazines affect the release of neurotransmitters such as serotonin, norepinephrine, and dopamine. A change in these would have the same effect as altering the weights at the inputs to the neuron. Lithium is metabolized by the body's electrochemistry in the same manner as is sodium, but it behaves differently in nerve conduction and firing potential. Thus lithium acts as an inert placeholder for the neuroactive sodium in the sodium-potassium complex. The presence of lithium would affect the threshold of the neuron, but this is just another weight in my model. Thus these psychoactive drugs are trying to counteract a medical problem that is manifested in a perturbation of the weights of the neuron. If the drugs are underprescribed, the desired effect will not be achieved, and if they are overprescribed, the weights may be totally scrambled, resulting in a worsening of symptoms.

Hardware Implementations

Recently, threshold logic has been receiving a lot of attention from the press. The front page of the *Electronic Engineering Times* carried an article on February 3, 1986, entitled "Neural Research Yields Computer That Can Learn." This article described research into a speech learning program based on Hopfield networks that apparently makes use of time feedback techniques similar to those outlined here.

The next week an article appeared in the same publication that touted threshold logic as the key to optical computers. This article gave some details on how electro-optical technology can implement threshold logic gates with an enormous number of inputs.

The week after that, an article appeared giving details of a gallium arsenide TLU that uses the analog addition of the brightness of light waves to perform the summing operation, so that the device is essentially a threshold detector with a photoresistor for an input. This TLU implementation does not increase in complexity no matter how many inputs it receives: they are just lights shining on its single photoresistor. The output of this device is a single solid-state laser. This last article also described a holographic optical interconnect scheme that is very interesting. The output lasers reflect off a hologram placed over the chip. The hologram acts as a phased array reflector that directs each output laser's light only to those photoresistors that are supposed to be connected to that output. In this way, the logic signals travel at the speed of light without wasting any chip real estate on signal interconnect lines. The logic can be placed closer together, and a 3-D medium is available for interconnect wiring instead of the 2-D masks of current-day chips. Gallium arsenide chips are now available that operate at speeds of 20 GHz. With more closely spaced circuits and more flexible de-

sign rules for interconnects, a tremendous increase in speed should be gained from these new devices.

This kind of hardware is just what is needed to take these learning systems from the several seconds per iteration speed zone into the picoseconds per iteration arena. You can certainly expect to see more threshold logic learning systems in the future if this hardware implementation effort succeeds.

Availability

All the source code for articles in this issue (except for C Chest) is available on a single disk. To order, send \$14.95 to *Dr. Dobb's Journal*, 501 Galveston Dr., Redwood City, CA 94063 or call (415) 366-3600 ext. 216. Please specify the issue number and format (MS-DOS, Macintosh, Kaypro).

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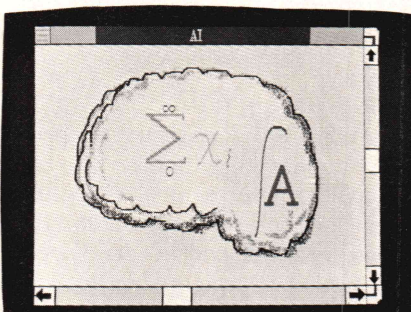
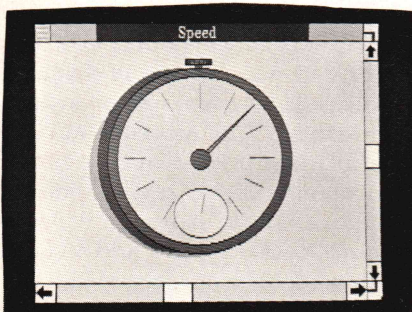
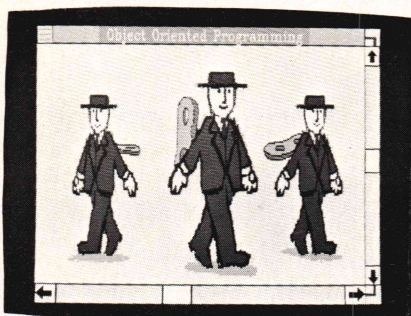
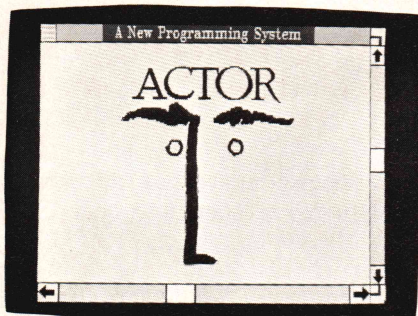
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Four PROLOGs for the Macintosh

by Dan L. Pierson

The growth in popularity of PROLOG has been vividly reflected in the products available for the Macintosh. Four PROLOGs have been released since January 1986; others have been announced or are rumored. This review covers the four PROLOGs that were available for the Mac as of November 1986: PROLOG/m, Version 1.10a; AAIS Prolog M-1.10; MacPROLOG, Version 1.0a; and ExperProlog-II, Version 2.32.

The Products

PROLOG/m

PROLOG/m from Chalcedony Software is a basic Edinburgh PROLOG interpreter. It and the IBM PC version, PROLOG/i, are the successors to the several-year-old PROLOG/V. The package includes a 184-page paperback *Language Reference and Tutorial*; a 30-page paperback manual; and a bootable, unprotected disk that contains the PROLOG/m program, the PROLOG library, a file of release notes, and a folder of example programs. Chalcedony also sells three packages of extension programs: the TOOLBOX, the TOYBOX, and NFL-Xpert. This review includes the TOOLBOX, a collection of 58 utility programs. Some of the TOOLBOX programs, such as `setof` and `bagof`, are standard parts of other PROLOGs. Other TOOLBOX programs, such as `avl_tree` and `h_list`, are useful tools that are not part of any other PROLOG. The TOOLBOX consists of a 72-page paperback book that contains the complete source of all the programs, explanations, and exam-

Dan L. Pierson, 10 Fort Meadow Dr., Hudson, MA 01749. Dan was one of the developers of the first release of VAX Common LISP. He is currently developing software for Unix.

*It seems that
PROLOG's
implementors
never considered
syntactic similarity to
be a goal.*

ples of use and a disk containing the program sources.

AAIS Prolog

AAIS Prolog is the newest of the products. The first shipments for the Mac were in September 1986 (there was an earlier Unix version), and the first update was shipped in late November. AAIS is a large, elaborate Edinburgh-based system. The AAIS Prolog package includes a 134-page, letter-size manual; the primer *Prolog Programming for Artificial Intelligence* by Ivan Bratko; a bootable, unprotected disk containing the PROLOG program and library; and a disk with a few example programs.

The November update to AAIS Prolog was supposed to include support for Macintosh graphics. Much to my surprise this support took the form of general, user-extendable support for both the entire Macintosh ROM and any additional programs in code resources. This means that anyone with access to an assembler or compiler that can produce code resources can extend AAIS Prolog simply by adding the resource to a copy of the PROLOG file using Apple's ResEdit and writing a small PROLOG program to load the resource and define the new predicates. Of course, this is not novice programming—the price for AAIS Prolog's flexibility is that graphics and window programming are much

more complicated than in a more limited, higher-level environment.

MacPROLOG

MacPROLOG is micro-PROLOG, the first dialect of PROLOG for microcomputers. Micro-PROLOG and its big sister sigma-PROLOG are currently available for MS-DOS, CP/M-86, CP/M-80, the Apple II, the Commodore 64, most Unix machines, VAX/VMS, and Data General machines running AOS. MacPROLOG is a complete, professional development system with many special features. The MacPROLOG package includes a PC-style ring binder containing a 61-page users' guide and a large reference manual; the primer *micro-PROLOG* by Clark and McCabe; an unbootable, unprotected disk containing the PROLOG program, the Generic (all three syntaxes) programming environment, a file of release notes in two formats (MacWrite and text), and a folder of example programs; a disk containing the Standard and Edinburgh programming environments; and a disk containing the Standard and Edinburgh run-time systems.

Two of the most impressive features of MacPROLOG are its support for three syntaxes with automatic conversion between them and its extensive support for the Mac interface. Predicates exist to perform simply and easily almost any task involving windows, menus, and dialogs. For example:

```
(SCROLL_MENU
  ["please select some" fruit]
  [apples pears peaches]
  [apples] _s)
```

displays a moded dialog box containing the prompt "please select some

fruit," a scrolling list of the fruit with apples highlighted, and an OK button. When the user clicks OK, the variable `_s` is unified with the selected fruit. Using the above facilities, a run-time system, and user-defined error handlers, an application can hide the underlying PROLOG completely. Given all this power, it's surprising that MacPROLOG provides absolutely no support for Macintosh graphics.

ExperProlog-II

ExperProlog-II is a polished, professional production of Alain Colmerauer's next-generation PROLOG. ExperTelligence advertises compatible versions for VAX/VMS and the IBM PC; the reference manual also mentions Hewlett-Packard (HP-150, HP-1000, HP-9000) and expands the IBM PC to include all MS-DOS machines. The package includes an attractive vinyl ring binder containing a 171-page reference manual and 132-page Macintosh users' manual; the primer *PROLOG* by Francis Giannesini et al.; a bootable, unprotected disk containing the PROLOG program, an initial saved system, and a demo program; and a disk containing example programs and the Lisa Pascal programs, object files, and link commands for a sample extension to Prolog-II.

ExperProlog-II provides extensive, fairly high-level support for Macintosh graphics and mouse input but very little menu support (extend one menu) and no support for dialogs or applications that hide the underlying PROLOG. User extensions to PROLOG could probably do most of this, but extensions currently require the Lisa Workshop—an uncommon, expensive, and obsolete development environment for the Mac.

User Interfaces

All four PROLOGs provide a basic Macintosh environment with a menu bar, desk accessory support, and an initial window. Table 1, right, summarizes the user interface features of the four products. The main interaction window is called a query window because you interact with a PROLOG system by asking it questions. The first three entries in the table refer to features of this query window. The next section refers to the program editor, if any. Only the AAIS edi-

tor is suitable for editing non-PROLOG text—the other editors are too closely tied to the PROLOG evaluation mechanism. MacPROLOG includes a Find Definition menu option that makes the correct window visible and positions the cursor at the start of the requested definition. Most of the PROLOGs report errors by a combination of an alert dialog, positioning the cursor, and highlighting the erroneous text. The method for interrupting a long running program varies from none in Prolog-II to using the Mac's Programmer's Switch to invoke a full debugger breakpoint in AAIS Prolog.

Debugger

All the PROLOGs provide some sort of debugger. The traditional PROLOG debugger is called a box debugger because it is based on viewing a PROLOG procedure as a box with two entries—call and redo—and two exits—fail and exit. With a full box debugger, tracing and breakpoints (called spy points) are individually controlled for each entry and exit in the box for each procedure. Individual control of the entries and exits is done by leashing or unleashing the interpreter for each type of entry or

exit. PROLOG/m provides full leashing and unleashing but few other commands. Prolog-II provides only an uncontrolled trace. The other two PROLOGs provide box debuggers without full leashing; the AAIS Prolog debugger provides a particularly rich selection of other options.

The last row in Table 1 shows how much free memory remained on a 512K Macintosh after starting the basic, fully loaded system. I couldn't determine this number for PROLOG/m. The other three PROLOGs provide options to remove features and save some memory. I didn't have time to reconfigure each PROLOG to see how much memory can be saved if all the optional features are stripped out.

The Dialects of PROLOG

PROLOG is more than merely another language that has never suffered the pangs of standardization; it is a language whose primary implementors seem never to have considered syntactic similarity, let alone compatibility, a goal. The four PROLOGs in this review support five distinct syntaxes, only one of which is merely a significant extension of another.

The smallest elements of a PROLOG

	PROLOG/m	AAIS Prolog	MacPROLOG	Prolog-II
Queries				
Scrolling	no	yes	dialogs ¹	yes
Editable	yes	yes	yes	yes ²
First/all	choice ³	pause ⁴	choice ⁵	all
Editor	no ⁶	yes	yes	yes
Multifile	—	yes	yes	no
Can query	—	yes	yes	no
Search	—	yes	yes	yes
Replace	—	yes	yes	no
Balance parens	—	no	option	auto
Find definition	—	no	yes	no
Errors				
Report	message	dialogs	dialogs	dialogs
Cursor	no	yes	yes	yes
Highlight	no	yes ⁷	yes	yes
Interrupt	command-	Programmer's Switch	Programmer's Switch	no ⁸
Debugger	box	box ⁹	box ¹⁰	trace
Free memory (bytes)	?	84,524	81,850	78,960

1. Multiple query dialogs can be open at a time; there is a default scrolling output window.
2. Special Edit Goals window.
3. Global menu/command choice.
4. Pause after each solution; type ';' for next solution.
5. Elaborate choices in each query dialog.
6. Can use an editor desk accessory.
7. Highlight removed when dialog is exited; dialog sometimes covers highlight.
8. Programmer's Switch interrupt is recoverable but leaves the screen messed up and rudely aborts the execution state.
9. No leash/unleash options but lots of stack display and execution modification commands.
10. Only interpreted predicates can be traced; all predicates can have spy points set on them.

Table 1: User interface

program are clauses. A clause consists of a functor and zero or more arguments. The number of arguments of a clause is the arity of the clause. A clause of zero arity is an atom. Clauses are the elements of rules. A rule consists of a head (the left-hand side) and a body (the right-hand side). The head of a rule consists of a single clause; the body consists of zero or more clauses. The head of a rule is true if and only if all the clauses in the body are true. A rule with no body is always true and is known as a fact. A set of rules whose heads all have the same functor and arity form a procedure. A procedure defines the meaning of a particular functor and arity, called a predicate. Because the same functor can have different meanings with different arities, predicates are typically referred to by both functor and arity, as in *plus/3* for plus with three arguments.

Edinburgh Syntax

The most common PROLOG syntax is called Edinburgh syntax after the Prolog-10 and C-Prolog systems developed at the University of Edinburgh. This syntax is used in the well-known PROLOG primer *Programming in Prolog*, the excellent new intermediate book *The Art of Prolog*, and many other books and papers on the language. Edinburgh is the only syntax that supports a wide selection of infix operators. All of the products except Prolog-II support the Edinburgh syntax, either natively or as an option.

A typical Edinburgh procedure looks like this:

```
reverse([], []).
reverse(X:XS, Zs) :-
    reverse(Xs, Ys),
    append(Ys, [X], Zs).
```

This is the famous "naive reverse" procedure for reversing a list. It reads: the null list is its own reverse; to reverse a nonnull list, concatenate the reverse of the tail of the list and the head of the list.

In Edinburgh syntax, clauses are expressed as *functor(arg1, ...)*, and rules are *clause :- clause [clause ...]*, where the commas between clauses mean *and*. Lists are ex-

pressed as comma-separated terms within square brackets; the head and tail of a list are indicated by a vertical bar. Thus *[X:XS]* means the list with head *X* and tail *XS*. Symbols start with a lowercase letter, whereas variables start with an uppercase letter. Arithmetic expressions are expressed as *X1 is X + 1*. Note that *X* and *X1* are different variables; once a PROLOG variable is bound to a value, it cannot be changed. Operators such as *is* and *+* can be freely defined with arbitrary precedence, associativity, and meaning. There are two types of comments: end-of-line comments starting with *'%*' and comment text bracketed by nonnesting *'/*'* and *'*/'* as in C. MacPROLOG's Edinburgh mode does not permit the end-of-line comment syntax.

AAIS Prolog's native syntax is an extension of Edinburgh syntax that supports AAIS' new features and data types. AAIS Prolog is about as similar to Edinburgh PROLOG as Common LISP is to its ancestor MacLisp.

The naive reverse procedure is exactly the same in AAIS and Edinburgh PROLOGs. Among the syntactic changes in AAIS Prolog are that *'c'* is a character instead of a small integer (but can automatically be treated as an integer when needed), *cat* is a string instead of a list of small integers, and *foo:append* is the symbol *append* in the package *foo*. Also, packages are a type of module; programs in one package will not see symbols of another package unless the program's package inherits from the other package.

Standard Syntax

MacPROLOG's native (Standard) syntax is LISP-like; everything is fully parenthesized and stored as lists. The naive reverse procedure is expressed in Standard syntax as:

```
((reverse ( ) ( )))
((reverse (X:XS) Zs)
 (reverse Xs Ys)
 (APPEND Ys (X) Zs))
```

The History of PROLOG

Interest in using formal logic as a programming language dates back to research in automatic theorem provers in the early 1950s. Robinson's 1965 paper¹ provided the necessary groundwork for a practical logic programming language. Hewitt's *PLANNER*,² although later recognized as a failure, was the first logic-based programming system. Cooperative research by Alain Colmerauer and Robert Kowalski resulted in the creation of the first PROLOG interpreter in the early 1970s.

PROLOG research and development continued in Europe during the 1970s. The two principle research groups were Colmerauer's group at the University of Marseille-Aix and the University of Edinburgh group, which included Robert Kowalski and David Warren. Warren was responsible for the next major breakthrough in PROLOG. His Prolog-10 compiler, the first high-performance PROLOG system, did much to dispel the belief that logic programming languages had to be horribly inefficient.

The Japanese gave PROLOG its next big boost when they decided to use

PROLOG instead of LISP as the basis of their Fifth Generation Project.

Though still controversial (see Carl Hewitt's attack in the premier issue of *AI Expert* magazine³), PROLOG is gaining force as the second major language for AI applications. Serious implementations of all the major dialects are available for most computers and operating systems from micros to mainframes. New language features are appearing to address many of the perceived shortcomings of basic PROLOG. Whether you believe in the virtues of PROLOG or not, the language is maturing as a real, long-term option in the programming world.

PROLOG is an important language to understand because it requires a new way of thinking about programming problems. PROLOG is a declarative, side-effect-free language with a predefined processing loop. The absence of side effects in "pure" PROLOG makes the language a serious candidate for parallel processing. Indeed, several concurrent languages based on PROLOG, such as Concurrent Prolog,^{4,5} have already appeared.

On Command: Writing A Unix-Like Shell for MS-DOS

by Allen Holub

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by Thom Hogan

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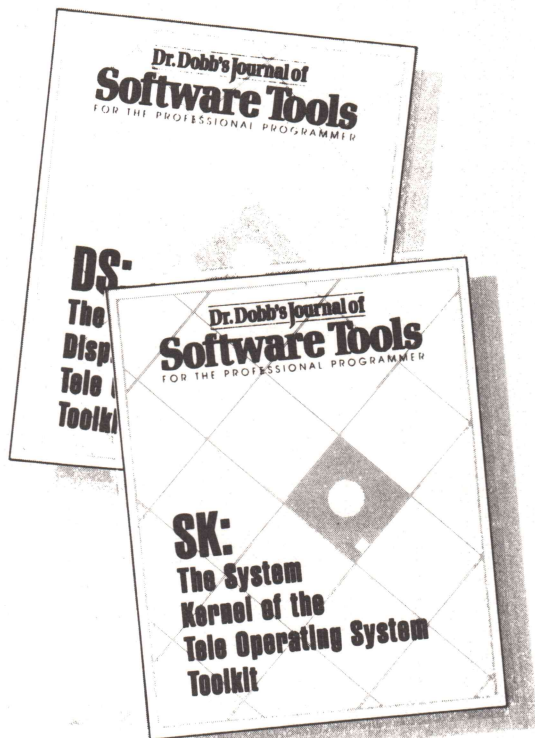
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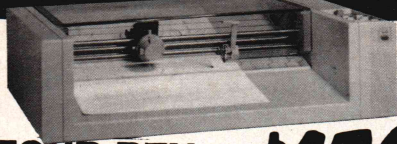


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**FOUR PEN
COLOR PLOTTER** **\$159**

The manufacturer has asked us not to publish their name. But this four color plotter was produced by one of the Worlds largest makers of personal computers.

The 410 color plotter will connect to the serial port of virtually any micro-computer. Simple ASCII commands direct one of the four color pens to draw circles, arcs or ellipses on paper or transparency material up to 11 by 17 inches. The plotter is capable of producing the full upper and lower case alphabet along with seven international character sets. Text can be printed horizontal, vertical or diagonal in sizes from 1/16 to 6 inches, slanted forward or backward to 85 degrees.

Enlargements or reductions are achieved through elaborate firmware. Pen travel is four inches per second with .004" pen resolution. Standard pens are available in an assortment of 32 different colors and widths.

The ideal plotter for architecture, CAD engineering or graphic design. At \$595 it was a great buy, at \$159 its a steal. Support packages for specific computers available. Manual only \$15 refundable upon purchase of plotter.

OTHER PLOTTERS AVAILABLE:

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Sweet P • CalComp... please call for prices.

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\$65
Quantity Two

These Qume double sided PC compatible drives bear the IBM logo. The drive was manufactured for IBM for use in the recently discontinued PC Junior computer. We have purchased a large quantity of these drives and are currently offering them in sets of two for only \$65 each.

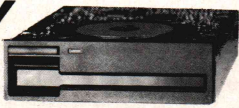
Panasonic AT Compatible

\$115

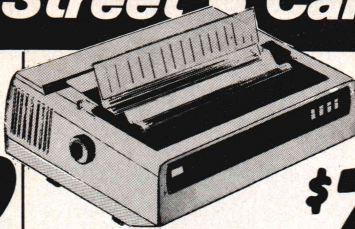
The Panasonic 475 is jumper selectable between 96 TPI format and 1.2 Megabyte as used in the IBM/AT computer. Suggested price of this drive is \$189 but because of unusual buying opportunity, California Digital is able to offer these drives at only \$115 each, quantity two.

	One	Two	Ten
QUME 142 half height	69	65	call
TEAC FD55BV half height	109	99	89
TEAC FD55FV 96 TPI, half ht.	119	109	105
TEAC FD55GF for IBM AT	169	159	155
PANASONIC 455 Half Height	109	99	89
PANASONIC 475 1.2 Meg./96	119	115	109
MITSUBISHI new 501 half ht.	129	119	109
MITSUBISHI 504A AT comp.	169	159	155
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Installation Kit with manual	10		
Dual enclosure for 5 1/4" drives	59		
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Scotch head cleaning kit	19		
Flip & File Storage tubs	15		

SONY
\$139



The Sony 53W is a 3 1/2 inch double sided double density disk drive. The drive can be connected to your existing floppy controller but will require MS/DOS 3.2 to properly operate in the PC and compatibles. The 53W is similar to the drive being used in the PC portable.



**80 Character
Daisy Wheel Printer** **\$759**

These Fujitsu Daisy Max 830 were manufactured for Motorola's Computer Division. The purchase order was canceled and Fujitsu was forced to liquidate these 80 character per second daisy wheel printers at "fire sale" prices.

Features: bullet proof construction, serial RS-232 interface, Diabolo 630 wheels and commands, programmable line spacing in increments of 1/96" and column spacing of 1/120". The printer is also capable of underscoring, bold overprint, shadow print, centers and justifies along with vector plotting.

Factory suggested price of the Daisy Max 830 was \$2495, while supplies last California Digital is offering this liquidated special at only \$759. Also available: tractor and sheet feeders.

Bernoulli Box

was \$3540 now only

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The Bernoulli Box by Iomega, features 10 and 20 megabyte removable cartridges, and delivers reliability, expandability, transportability, security and speed in one versatile subsystem. It lets you transfer megabytes of information safely and swiftly for primary or backup storage. Or combine several software programs onto a single cartridge for easy switching from one to another.

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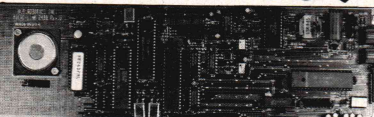
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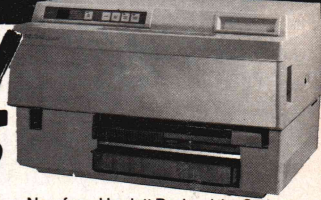
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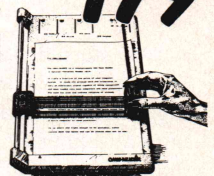
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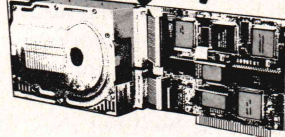
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A Challenge to Microsoft® C...

We challenge Microsoft C (Ver 4.0) to a C compiler duel to the finish, measuring compile, link, and execution times. If they win, we will stop advertising for two months.

by Roy Sherrill

If Microsoft C (Ver 4.0) can beat our new C compiler, Optimum-C then we will stop advertising in all magazines and publications for two full months and win or lose we will publish the results in its entirety. Even the Microsoft ads say "The Fastest C you've ever seen," so let the challenge begin.

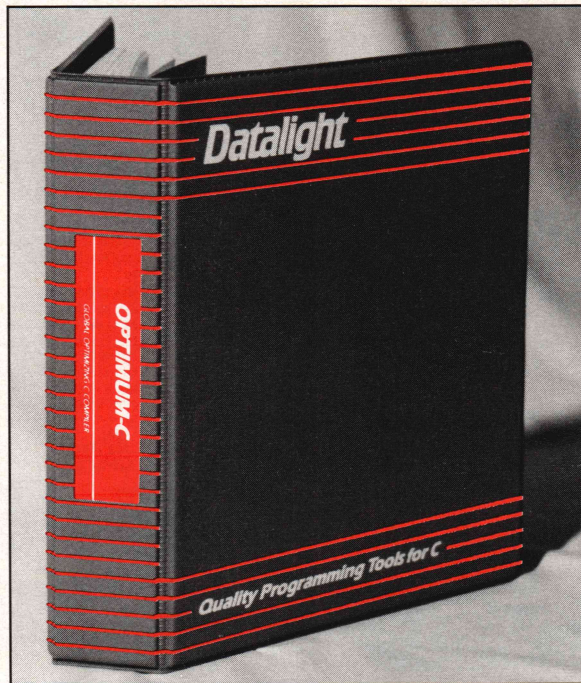
Walter says Optimum-C is better

It all started when Walter Bright, the developer of Optimum-C, was explaining his new global optimizing C compiler and how it's code would be faster than Microsoft C (Ver 4.0). Walter and I were frustrated because here we had a C compiler that would beat Microsoft C on 7 out of 10 benchmarks and also compile and link faster; yet our marketing consultant, Mark Astengo, told us that Microsoft C had a lock on the C compiler market and by 1990 they would probably have an 80% market share. Then Mark said, "Roy, if your C compiler is as fast as you say it is, why not challenge Microsoft C to a duel? Furthermore, if Microsoft wins, Datalight should stop advertising for two months and print the results of the test, win or lose." Well, I've always been one for a challenge. So here it is...

We only ask the following...

The benchmark suite will consist of the set of programs that Microsoft supplied to *Computer Language* for their February 1987 C compiler review issue. Microsoft will make available the programs to Datalight at least two weeks prior to the benchmarking. The benchmarking will be between Microsoft C 4.0 and Optimum-C. It will occur at a mutually agreed upon time and place. Interested individuals will be allowed to attend. The benchmarks will be compiled and run on a standard IBM PC-AT.

There will be two separate tests for each program: compile and link speed, and execution speed. For each test, a representative from each company will set up the compiler so that it performs at its best.



Optimum-C challenges Microsoft C Version 4.0 to a duel, yet is priced at only \$139 (includes free learn C tutorial) which is one-third suggested retail price of Microsoft C Version 4.0

The benchmarks will be adjusted so that they take sufficiently long to run, that the tolerance involved in timing them is insignificant. The winner is determined by the compiler with the faster execution times for the majority of the benchmarks. We'd like an answer from Microsoft no later than April 1, 1987.

So what's a global optimizer?

A global optimizer looks at an entire function at once, analyzing and optimizing the whole function. A technique called data flow analysis is used by Optimum-C to gather information about each function. This enables your compute-bound programs to execute as much as 30% faster after global optimization. But there is one catch... because the global optimizer ruthlessly searches for ways to speed-up execution speed and minimize memory usage, it has relatively slow compile times. No need to worry, though, because you can merely turn the global optimizer off. In fact, you can select which optimizations are desired. Listed on the next page are 12 optimizations. It's your choice: all, none, or partial...

Optimum-C Version 3.0

- ♦ Full UNIX System 5 C language plus ANSI extensions
- ♦ Fast/tight code via powerful optimizations including common sub-expression elimination
- ♦ DLC one-step compile/link program
- ♦ Multiple memory model support
- ♦ UNIX compatible library with PC functions
- ♦ Compatible with DOS linker and assembler
- ♦ Third-party library support
- ♦ Automatic generation of .COM files
- ♦ Supports DOS pathnames, wild cards, and Input/Output redirection
- ♦ Compatible with Lattice C version 2.x
- ♦ Interrupt handling in C
- ♦ Debugger support
- ♦ ROMable code support/start-up source

MS-DOS® Support Features

- ♦ Mouse support
- ♦ Sound support
- ♦ Fast screen I/O
- ♦ Interrupt handler

MAKE Maintenance Utility

- ♦ Macro definition support
- ♦ MS-DOS internal commands
- ♦ Inference rule support
- ♦ TOUCH date manager

Tools in Source Code

- ♦ cat—UNIX style "type"
- ♦ diff—Text file differences
- ♦ fgrep—fast text search
- ♦ pr—Page printer
- ♦ pwd—Print working directory
- ♦ wc—Word count

1. Constant propagation
2. Copy propagation
3. Dead assignment elimination
4. Dead variable elimination
5. Dead code elimination
6. Do register optimizations
7. Global common subexpression elimination
8. Loop invariant removal
9. Loop induction variables
10. Optimize for space
11. Optimize for time
12. Very busy expressions

Quite frankly, if it were not for the global optimizer we would be much more timid in regards to our Microsoft challenge. So, if you want minimum compile and link times with good code execution speed, then compile without the optimizer; and if you want the fastest possible execution time, use our global optimizer.

Choose from five memory models

Speed your programs by selecting the memory model that best suits your application.

Memory Models		
Model	Code	Data
Compact	64k total code & data	
Small	64k	64k
Program	1M	64k
Data	64k	1M
Large	1M	1M

Compiling, one step...

Now with the one step DLC program you can create .OBJ, .EXE and .COM files. Also, DLC can handle multiple files and run MASM on your assembly files.

Includes complete source code for library

The UNIX-compatible library includes complete source code. Experienced programmers can use the source code to configure and rebuild the library to suit the application.

Third party library support includes Light Tools (Blaise), ZVIEW (Data Management Consultants), MASM (Microsoft), JACK (Cracker Jack), APL2C (Lauer Software), BTREE, ISAM (SoftFocus), Vitamin C (Creative Programming), DSD (Soft Advances), with more on the way.

One concise manual says it all in under 300 pages

If you are tired of wading through reams of documentation, worry not, because Optimum-C includes one complete and concise programmer's manual. The manual is delivered in an

IBM-style 3-ring binder which includes nine chapters, appendices, and easy-to-follow examples.

Dr. DOBBS and COMPUTER LANGUAGE Agree

Even though they reviewed our compiler before it had our global optimizer, both *Dr. Dobbs* and *Computer Language* were surprised by Datalight's performance. Read what they said...

"Reviewing this compiler was quite a surprise for us. For such a low price, we were expecting a "lightweight" compiler. What we got was a package that is as good as or better than most of the "heavyweights." Datalight C implements a complete C language. It also compiles quickly, doesn't take up much disk space, and looks impressive in the benchmarks."

DR. DOBBS, August 1986

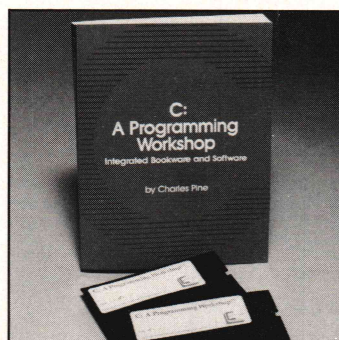
"This is a sharp compiler!... what is impressive is that Datalight not only stole the compile time show completely, but had the fastest Fibonacci executable time and had excellent object file sizes to boot!"

COMPUTER LANGUAGE, February 1986

Switch to C and we'll help!

Even if you have never programmed in C before, you'll find the C tutorial included free with Optimum-C a real time saver. If you don't have need for a C tutorial give this to a friend. (It's a \$49 value) This combination workbook and floppy disk will lead you through the C language with tutorials, quizzes, and program exercises.

*FREE C TUTORIAL!



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ADAM GREEN, INFO WORLD January 27, 1986

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If you are not 100% satisfied, simply return Optimum-C in it's original carton within 30 days for a full refund.

To order Optimum-C risk free with your credit card, call toll free or send your check for only \$139 (plus shipping and handling).

O.K. Microsoft, it's up to you. We've put two months of advertising on the line that says you can't beat Optimum-C to a real test. Your answer, please?

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MAC PROLOGS

(continued from page 32)

Clauses are expressed as (*functor* *arg* [*arg*...]) and rules are (*clause* [*clause*...]). Lists are a parenthesized sequence of terms, and a rule is a list. As in Edinburgh syntax, a vertical bar separates the head and tail of a list. Symbols start with any alphabetic character. Variables are distinguished by a leading underscore. Arithmetic expressions are expressed as (+ _x 1 _x1); infix operators are not available.

Multi-element structures with compact storage similar to Edinburgh clauses are available as tuples expressed as <a_b 1>; special functions are provided to compose and access tuples. Comments are bracketed with nonnesting '/' and '/'. This syntax is alleged to make it much easier to write programs that manipulate other programs.

Simple Syntax

MacPROLOG also supports Simple, an English-like syntax for beginning

PROLOG students. It is used in several primers, including *micro-PROLOG*. The naive reverse procedure in Simple syntax is:

```
(_X) reverse (_X)
(_X _Y!_Xs) reverse _Zs
if(_Y!_Xs) reverse _Ys
and append (_Ys (_X) _Zs)
```

Clauses are expressed as *functor* (*arg* [*arg*...]) or *arg functor* or *arg1 functor arg2*. Rules are built of clauses, conditions, and conjunctions. In the preceding example, *and* is a conjunction and *if* is a condition. Lists, symbols, variables, and comments are the same as in Standard syntax. Simple arithmetic expressions are as in Standard syntax, but complex expressions such as:

```
(SUM (X + Y / 5) Z X1)
```

are possible.

A New Model

The naive reverse procedure in Prolog-II is:

```
reverse(nil, nil) -> ;
reverse(X.X-tail, Z) ->
    reverse(X-tail, Y)
    append(Y, X.nil, Z);
```

Clauses are still expressed as *functor*(*arg*,*arg*...), but rules are now *clause* -> *clause*[*clause*];. The -> ; is required even for a fact. Lists are expressed as a series of terms separated by '.' and ending in *nil*. List head and tail are expressed as *X.X-tail*. Symbols start with at least two alphabetic characters. The rest of the symbol can contain dashes but not underscores. Several extended characters in the Mac's character set are treated as alphabetic, so symbols such as *Ægis* are legal. Variables start with one alphabetic character, optionally followed by any number of digits, optionally followed by any number of apostrophes, optionally followed by a dash and any symbol. This allows such names as *x*, *x1*, *X''*, and *X-the-first* but disallows such mnemonic names as *Premise* and *Denial*. Arithmetic expressions are expressed as *val*(*add*(*X*,1),*X1*). Comments are strings surrounded by ". Comments cannot span lines and cannot appear within the rules defining a single function (for example, an









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end-of-line comment after the first rule of naive reverse would be illegal). Program lines indented with tab characters cause syntax errors, such as "A SIMPLE TERM IS EXPECTED," with the cursor positioned near the tab but nothing highlighted.

Prolog-II terminology can confuse programmers who are used to earlier versions of PROLOG. Where other PROLOGs refer to "rules" and "unification," Prolog-II talks about "trees" and "deletion." There is a reason for the change in terminology. Prolog-II is based on a new, expanded, theoretical model, which adds the concept of inequalities between trees to the earlier PROLOGs' equalities. This feature, encapsulated in the built-in rule *dif*, adds a great deal of power to Prolog-II.

Prolog-II's other new features include infinite trees and error handling. Infinite trees, which consist of otherwise finite trees with loops, provide direct PROLOG support for the directed graph structures found in such applications as finite-state automata and grammars. Error handling in Prolog-II is based on the primitive *block*, which provides a simple form of signal handling. All Prolog-II's standard run-time errors signal with *block-exit* so that a program can handle the error. Previous PROLOGs either exit fatally on error or treat errors as failure; neither approach is really adequate for building production programs.

Prolog-II is missing some "inessential" features of earlier PROLOGs. Integers cannot be negative, though real numbers can be. Several layers of syntactic sugar have been removed. The Prolog-II list syntax resembles the basic dot syntax that earlier PROLOGs and LISP hide with a more readable list notation. The omission of operators makes many programs that manipulate symbolic structures less readable. The variable naming rules and the restriction on placement of comments interact to require a coding style in which initial block comments and mnemonic rule names are the main aids to creating readable programs. The sample programs in *PROLOG* and the Prolog-II manual use sparse one-line header comments and one- or two-character variable names.

Prolog-II is a different language from the other PROLOGs. The syntax differs from Edinburgh and Standard

in almost every respect: the terminology is different, and many of the language features are different, new, or missing. Converting an Edinburgh PROLOG program to Prolog-II is on the

same order of difficulty as converting a C program to Modula-2. Prolog-II is a new language with powerful new features. It is theoretically more powerful than older PROLOGs,

	PROLOG/m	AAIS Prolog	MacPROLOG	Prolog-II
Atoms	yes	yes	yes	yes
Clauses	yes	yes	yes	yes
Rules	yes	yes	yes	yes
Lists	yes	yes	yes	yes
Characters	no	yes	no	yes
Integers	yes	yes	yes	yes ¹
# of bits	16	32	28 ²	24
Floats	yes	yes	yes	yes
# of bits	64	64	64	64 ³
Strings	no	yes	no	yes
Arrays	no	no	no	yes
I/O streams	no	yes	no	no
Buffers	no	no	no	yes
Infinite trees	no	no	no	yes

1. Nonnegative integers only.
2. Documentation states range is -99,999,999 to +99,999,999.
3. Inferred from external procedure conventions.

Table 2: Data types

	PROLOG/m	AAIS Prolog	MacPROLOG	Prolog-II
Multistream	no	yes	yes	no
Random	no	yes	yes	no
Backtrackable input	no	yes	no	no
Pretty printing	no	yes	no	no
Tree drawing	no	no	no	yes

Table 3: Input/output extensions

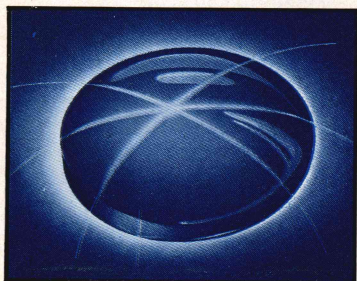
	PROLOG/m	AAIS Prolog	MacPROLOG		Prolog-II
			Standard	Edinburgh	
Cut	!	!	/	!	/
Backtracking	yes	yes	yes	yes	yes
Negation by failure	not	not	NOT	not	— ¹
Disjunction	;	;	OR	;	—
If	->	->	IF	->	default
Else	; or !	;	²	;	²
Iteration over	repeat	repeat	—	repeat	—
Solutions	forall ³	—	FORALL	—	—
Lists	—	foreach	MAP	map	—
		foreachlist			
Numbers	—	for	—	—	—
Collection	bagof ³	bagof	BAGOF	bagof	—
	setof ³	setof	SETOF	setof	list-of
			ISALL	findall	
Delayed evaluation	—	—	—	—	freeze
	—	—		TOHOLLOW	dif
				TOGROUND	
Inequality	—	—	—	—	dif
Signals	—	—	⁴	⁴	block
					block-exit
Dynamic invocation	call	call		call	—
		apply			
Metavariables	X	X	—X ⁵	X	—

1. Example in the primer—not normally defined.
2. Part of the *If* predicate.
3. In the TOOLBOX.
4. Program-defined error handlers for each error number.
5. The MacPROLOG metavariable facility is exceptionally powerful.

Table 4: Control features

SAPIENS STAR SAPPHIRE

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★

The Compiler is designed for use in developing programs directly on the PC and for porting applications written on larger machines down to the PC market.

★

SYSTEM REQUIREMENTS:

The system requires a DOS-based C compiler which supports huge model. It needs 640K RAM and a hard disk. Programs developed with *Star Sapphire* will run on a system with 256K of RAM. A hard disk is recommended for large applications. The virtual memory manager uses 16-128 kilobytes of RAM at the programmer's discretion.

★ ★ ★ \$495.00 ★ ★ ★

Sapiens Software Corporation
P.O.Box 7720, Santa Cruz, CA 95061
(408) 458-1990

MAC PROLOGS (continued from page 37)

though I feel it is less readable.

Features

Tables 2—6, pages 37 and 38, summarize the language features of the different PROLOGs. A few entries need more explanation.

Backtracking

Backtrackable input (Table 3) involves one of the traditional problems in PROLOG design—how to rec-

oncile the side-effect-free, backtracking world of logic programming with the side-effect- and state-based external world. The PROLOG language compromises by making I/O operations nonbacktrackable. When *foo(S)* fails in:

```
try(S) :- read(S), foo(S).
```

PROLOG will not backtrack and retry *read(S)*. Although this strategy is usually fine, it does make some loops harder to write (what if you wanted to keep reading clauses until you

	PROLOG/m	AAIS Prolog	MacPROLOG	Prolog-II
Database				
modification	yes	yes	yes ¹	yes
Rule access	yes	yes	yes	yes
Keyed database	no	yes ²	no	no
Assignment	no	set_global	remember	assign
Read variable	no	get_global	recall, default	val
Deletion	no	no	forget	no
Properties	no	no	yes	no

1. To a separate interpreted database.
2. Imperfect emulation of the Prolog-10 feature because of the different (hashed) internal structure of the AAIS database.

Table 5: Side-effect features

	PROLOG/m	AAIS Prolog	MacPROLOG	Prolog-II
Modules	no	packages	no ¹	worlds
Grammar	no	yes	no	no
Full char set	no	no	yes ²	partial ³
Mac interface	no	yes ⁴	yes	a little
Graphics	no	yes ⁴	no	yes
Other toolbox	no	yes ⁴	no	no
Other language	no	yes ⁵	no	yes ⁶
Click icon	yes	yes	yes	yes
Saves system	no	no	yes	yes
Run-time system	no	no	yes ⁷	no

1. The primer mentions a module system in other versions of micro-Prolog.
2. No choice of font; extended chars are not alphanumerics.
3. Special font (enhanced Monaco) provided.
4. Direct, complete support for the Mac Toolbox.
5. Like Toolbox support, but for arbitrary code resources.
6. Requires Lisa Workshop.
7. Special license required for redistribution.

Table 6: Other features

	PROLOG/m	AAIS Prolog	MacPROLOG			Prolog-II
			interp	comp	opt	
Reverse 30	11.8	0.7	2:13.1*	2.1	1.4	1.8
LIPS	42	709	—	236	354	276
Reverse failed	50	60	30	90	240	50
Map coloring	4:12.0	14.3	4:05.6	8.0	6.2	40.0
With dif						7.7
Graph connect	4.2	0.7	4.8	1.4	1.3	
Sieve 100	26.2	3.3	2:48.4*	10.7	10.7	5.7

* Ran out of memory after listed time.

Table 7: Benchmark results (minutes: seconds)

found one that satisfied $foo(S)?$). AAIS Prolog provides an additional set of input predicates that retry when backtracked to.

Control Structures

Table 4 has a lot of information crammed into it. Each row represents a control structure. The entries in each row are the name(s) of the control structure in that PROLOG, — means the control structure isn't supported in that product, and an empty space means that this row is a continuation of the preceding one because some product has more than one dis-

tinct predicate for that control structure. Negation by failure is the weak analogue of true negation used in PROLOG. Dynamic invocation is the ability to execute a clause bound to a variable. Metavariables are an extension of dynamic invocation—most PROLOGs treat a variable found where a clause would be expected as implicit dynamic invocation. MacPROLOG also allows metavariables in other positions, such as a metavariable as all or part of the body of a clause.

Side Effects

PROLOG is mainly a side-effect-free

language; good PROLOG programs make minimal use of side effects. But many programs can't be written without some side effects (see Table 5). The first two items refer to the earliest form of PROLOG side effects. PROLOG rules and facts are stored together in a memory database. The earliest PROLOGs provided special predicates to access and modify this database in order to bootstrap up the PROLOG environment. Of course, programmers began to use these predicates for other reasons such as including self-modifying code. Although excessive use of the database predicates is slow,

Books

➔ Bratko, Ivan. *Prolog Programming for Artificial Intelligence*. Reading, Mass.: Addison-Wesley, 1986. Paperback, 423 pages.

This is a new book that will be included as part of AAIS Prolog by the time you read this review. My copy hasn't arrived yet, so I can't say anything more about it.

Clark, K. L., and McCabe, F. G. *micro-PROLOG*. Englewood Cliffs, N.J.: Prentice-Hall, 1984. Paperback, 401 pages.

Although there are several micro-PROLOG primers, this is the official one. It is also the only one I know of that goes beyond elementary use of the Simple syntax to teach the possibilities of the whole language. The last section of the book, Applications of micro-PROLOG, consists of individual articles by different authors, including a critical-path-analysis program; two chapters on search, pruning, and game playing; and, you guessed it, the obligatory expert system example.

Clocksin, W. F., and Mellish, C. S. *Programming in Prolog*. 1st ed. Berlin: Springer-Verlag, 1981. Paperback, 279 pages.

This is the classic PROLOG text. The first PROLOG textbook, it is one of the main reasons for the "Edinburgh standard." This standard is really the core PROLOG that Clocksin and Mellish derived from the existing Edinburgh PROLOG systems for this text. Although of great historic importance, later and better PROLOG texts are now available.

Giannesini, Francis; Kanoui, Henry; Pasero, Robert; and van Caneghem, Michal. *PROLOG*. Reading, Mass.: Addison-Wesley, 1986. Paperback, 260 pages.

This is the Prolog-II primer. It is clearly written and quite readable. The last chapter includes a good deal of material on parsing natural languages and compiling grammars as well as the obligatory expert system example. If you're interested in Prolog-II, this is the best introduction you'll likely to get. If you buy Exper-Prolog-II, you get it as part of the package.

Sterling, Leon, and Shapiro, Ehud. *The Art of Prolog*. Cambridge, Mass.: MIT Press, 1986. Hardback, 427 pages.

This is the book I am using to learn PROLOG. It is an excellent first text for experienced programmers who don't want to bother with a primer. It is also an excellent classroom text. The book is divided into four roughly equal parts: Logic Programming, The Prolog Language, Advanced Prolog Programming Techniques, and Applications.

The first part, Logic Programming, is one of the book's greatest strengths and weaknesses at the same time. Its goal is to teach the ideas and techniques of logic programming before getting in to the quirky details and hackery of a specific language. The problem is that it is full of logic programs that look exactly like the PROLOG programs in the book. Many of the logic programs such as:

```
plus(0,X,X) <-
    natural_number(X).
```

```
plus(s(X),Y,s(Z)) <-
    plus(X,Y,Z).
natural_number(0).
natural_number(s(X)) <-
    natural_number(X).
```

cannot execute in PROLOG. Novices studying alone are likely to enter these programs and become very confused when they don't work.

Advanced Prolog Programming Techniques develops examples such as Eliza, a parser for grammar rules, an alpha-beta pruning search, a PROLOG tracer, and the obligatory simple expert system shell.

The Applications section of the book consists of the chapters "Game Playing Programs" (Mastermind, Nim, and Kalah), "A Credit Evaluation Expert System," "An Equation Solver," and "A Compiler" (to an abstract assembly language).

The second main flaw in this book is the number of typos, especially in the programs. I suspect that this may be partly a result of the new process used to produce this book. The authors and assistants produced the book using TEX and sent the camera-ready copy to MIT Press, which published it without further ado. I'm sure this new process is faster and cheaper, and it certainly produced an attractive book, but I wonder if the increased speed has dropped too many proofreading steps.

All in all, I highly recommend this book to anyone who is familiar enough with programming in general to avoid the pitfalls and to PROLOG beginners looking for a more advanced book to follow their primer. ☐

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MAC PROLOGS

(continued from page 39)

hard to understand, and generally bad form, some use of them has true advantages in both speed and power. Such powerful predicates as *setof* would not be possible without database modification.

Other Features

Grammar (Table 6) refers to definitive clause grammar rules. This special syntax for defining a useful subset of natural-language grammars is described in *Programming in Prolog* and *The Art of Prolog*.

None of the PROLOGs can create true stand-alone applications. Click icon means that a program icon can be double-clicked to automatically start the PROLOG with that program loaded. All the PROLOGs permit the loaded program to take control as it starts for a poor-man's application.

Vendors

PROLOG/m

Chalcedony Software Inc.
5580 La Jolla Blvd., Ste. 126
La Jolla, CA 92307
(619) 483-8517
\$99.95, PROLOG/m
\$29.95, TOOLBOX
\$29.95, TOYBOX
\$49.95, NFL-X-pert
Reader Service Number 27

AAIS Prolog

Advanced A.I. Systems Inc.
P.O. Box 39-0360
Mountain View, CA 94039
(415) 961-1121
\$150
Reader Service Number 28

MacPROLOG

Programming Logic Systems Inc.
31 Crescent Dr.
Milford, CT 06460
(203) 877-7988
\$295, MacPROLOG
\$100, optimizing compiler
Reader Service Number 29

ExperProlog-II

ExperTelligence Inc.
559 San Ysidro Rd.
Santa Barbara, CA 93108
(805) 969-7871
\$495
Reader Service Number 30

Prolog-II allows the entire state of the PROLOG to be saved in binary form so that a development or application can be restarted quickly. MacPROLOG provides two minimal run-time systems, but the run-time system, MacPROLOG itself, and your compiled code must all be on the disk in order to run the program.

The Benchmarks

The most common metric of PROLOG performance is LIPS, logical inferences per second. This is no more useful than MIPS, but I've done it anyway. The second row of Table 7, page 38, is a LIPS figure calculated by dividing the time for naive reverse of 30 elements—the most common PROLOG benchmark. The third row of Table 7 is a measure of memory utilization. It is the length of a list that caused a memory or stack-full error message from naive reverse. List sizes of 30, 50, 60, 90, 120, 180, and 240 were used in the test.

Map coloring is a simple generate-and-test recursive loop. This sort of thing is fairly common in PROLOG applications. Graph connect uses a lot of database hacking with *asserta* and *retract*. Sieve is, of course, the traditional *Byte* sieve benchmark. I included it to give some idea of the arithmetic performance of the PROLOGs.

AAIS Prolog comes up with about twice the LIPS of the MacPROLOG optimizing compiler here, but the ratings are reversed with a more complicated benchmark. Both the MacPROLOG compilers handily won the map coloring test. The compilers, especially the optimizing compiler, had much better memory utilization than any of the interpreters. The number of resolutions in a naive reverse of length N is the triangular number of $N+1$ —that is $(N+1)(\text{ceiling}((N+1)/2))$. Reverse of 30 takes 496 resolutions, 60 takes 1,891, 90 takes 4,186, and 240 takes 29,161 resolutions. The advantage of *dif* is also clear, improving Prolog-II's performance on map coloring by a factor of 5.

Conclusions

PROLOG takes a lot of memory. All these products are really cramped on a 512K Macintosh.

These are four very different products. For learning PROLOG and playing with it at home, I'd recommend

AAIS Prolog. It's fast; has many features, including unlimited potential use of the Mac environment; and the price is reasonable. For serious research, development, or prototyping in which graphics are not an issue, I'd definitely consider MacPROLOG as well. Its memory-efficient compilers and easy use of the Mac user interface make it well worth considering. Prolog-II has a powerful and interesting base language, but the price is high and both the user interface and language are less convenient than the other PROLOGs. Buy it if you like the Prolog-II language model or need its features; otherwise, wait until its vendor lowers the price. The only PROLOG I cannot recommend at all is PROLOG/m. It's not bad by itself, but it's just not competitive. For only a little more money you can get AAIS Prolog.

If you are determined to ship a Macintosh product in PROLOG, you need two features: the ability to supply your own user interface and some sort of run-time system. Only MacPROLOG comes close to meeting these requirements. It meets the first requirement easily, but I'm not convinced by a "run-time system" that requires that both the language interpreter and the run-time system file go along with the application on every disk.

Notes

1. J. A. Robinson, "A Machine-Oriented Logic Based on the Resolution Principle," *Journal of the ACM* 12 (January 1965): 23–41.
2. C. E. Hewitt, "PLANNER: A Language for Proving Theorems in Robots," *Proceedings of IJCAI-69* (Washington, D.C.: International Joint Conference on Artificial Intelligence, May 1969): 10.
3. C. E. Hewitt, "Concurrency in Intelligent Systems," *AI Expert* (San Francisco: CL Publications, 1986): 44–50.
4. E. Shapiro, *Concurrent Prolog* (Cambridge, Mass.: MIT Press, 1987).
5. K. Kahn, E. D. Tribble, M. Miller, and D. Bobrow, "Objects in Concurrent Logic Programming Languages," *OOPSLA '86 Conference Proceedings*: 242–257.

DDJ

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MYCIN-Like Expert Systems

by Richard W. Grigonis

For Amiga owners interested in artificial intelligence but lacking Amiga LISP, Metacomco's Cambridge LISP 68000, XLISP, or Micro Forge PROLOG, here is an interesting approach to setting up a quick expert system using the Amiga BASIC package that you already own. By now you've probably noticed that this is the best Microsoft BASIC interpreter ever written (so good, in fact, that it almost isn't BASIC), and further improvements are on the way.

Rule-Based Systems

As all readers of *DDJ*'s special AI issues are aware, most expert systems are essentially a collection of production rules and are therefore known as rule-based systems (RBSS). The rules have a left-hand side (the antecedent, or propositions combined in logical AND/OR form that comprise a situation) and a right-hand side (the consequent, goal, or action to be taken).

A simple rule is as follows:

```
IF Left-hand side
  THEN Right-hand side
IF X has hair
  THEN X is a mammal.
```

Notice how the rules of an RBS are simple modules of logic, taking the form of *IF...THEN* statements. The *THEN* sections of some rules match the *IF* sections of others, forming an inference network that can be drawn as an AND/OR tree. The rules themselves are quite useless unless the program also possesses an inference engine that searches through the rules in one of two ways. If the situation on the left side is examined first and the

An approach to setting up an expert system with BASIC

right side is taken as the action, then the system can be said to be a bottom-up, forward-chaining one. If, however, the right side is examined first and taken as a goal or hypothesis to be proved by demonstrating the truth of the propositions on the left side, then such a system is a top-down or backward-chaining one.

MYCIN for the Masses

Perhaps the most famous backward chaining, depth-first search expert system is MYCIN, which was also one of the first major expert systems and is still used as a sort of benchmark in comparing expert systems. MYCIN has 450 rules that are used to diagnose and suggest antibiotic treatment for 100 blood and meningitis infections. The program listing accompanying this article (Listing One, page 74) is a simple MYCIN-like program written as a demonstration of such a system in Amiga BASIC. It took just a few hours to port the original version to the Amiga from another one of Jay Miner's hardware creations, my old Atari 800. In fact, a few line numbers from the original still exist in the Amiga BASIC code, serving as labels.

Instead of diagnosing diseases on the basis of symptoms, the program in the listing identifies animals on the basis of physical attributes and observed behaviors. It is a toy system designed to demonstrate the MYCIN reasoning mechanism in Amiga BASIC. You can find the knowledge base

of rules it uses on pages 242–243 of Winston and Horn's textbook *LISP*.¹

The problem with writing expert systems in BASIC as opposed to PROLOG is that the inference engine necessary to parse the knowledge base of rules and to drive a path through them must be written by the programmer.

You can store production rules as *DATA* statements as follows:

```
DATA Rule 1,IF,has hair,
  THEN,is mammal
DATA Rule 2,IF,gives milk,
  THEN,is mammal
```

Unfortunately, as most BASICs are not recursive, programming a general-purpose top-down parser to act upon these *DATA* statements requires considerable effort. You must establish push-down stacks, queues, stack conventions, and so on to store local variables for the reentrant subroutines of the inference mechanism. Another problem with a general-purpose parser of this type is that the processing overhead needed to search through the knowledge base of production rules and keep track of what is going on results in a slow program, although it is versatile. Code for a BASIC expert system using *DATA* statements such as the preceding ones, along with a stack, backward-chaining, and the Winston and Horn rules (but without the MYCIN certainty factor inference routines) can be found in the September 1981 issue of *Byte*.²

Elegant BASIC?

The (supposedly) quick-and-dirty approach I have elected to use for developing an Amiga BASIC expert system requires a bit more code for each rule, but it forces the BASIC interpret-

Richard W. Grigonis, 49 Haring St., Bergenfield, NJ 07621. Richard is a freelance programming consultant.

er (via its own stack) to handle the bookkeeping required for searching through the rules in a top-down, backward-chaining, depth-first manner. A single stack is employed, but only to keep track of what routines have been activated so that the system can explain its reasoning to users when they key in "why" or "why?" in response to a question from the system. Otherwise, the expert system is herein presented in a form similar to—though not exactly the same as—a syntax-directed recognizer, such as those used in computer language interpreters and compilers.

A BASIC interpreter, for example, can be constructed from these production rules:

```
<statement> ::=
  LET <identifier> =
      <expression>
<statement> ::=
  NEXT <identifier>
<statement> ::=
  INPUT <identifier list>
<statement> ::=
  GOTO <line number>
<statement> ::=
  FOR <identifier> =
      <expression>
  TO <expression>
<statement> ::=
  GOSUB <line number>
```

Systems programmers writing a BASIC interpreter based upon these rules must now write a syntax-directed recognizer in C or assembly language that can parse all the kinds of BASIC language statements shown above. They do this by writing separate recognizer procedures for each nonterminal in the language, with one procedure calling others as dictated by the production rules. For the preceding rules pertaining to BASIC statements, John Zarrella³ suggests one possible syntax recognition procedure (see Example 1, right).

Because an expert system is also based upon production rules, programmers can examine the components of each rule and write recognizer procedures or subroutines in a high-level language in the same manner as with the BASIC interpreter discussed previously.

In constructing such a program, you must write a subroutine for each nonterminal and terminal in the lan-

guage or, as in this case, each hypothetical fact, assertion, or combined assertion to be proven. The "words" analyzed by this expert system syntax-directed recognizer are the numeric values supplied by users in response to questions asked by the program. In other words, each hypothesis (albatross, penguin, ostrich, zebra, and so on) is a subroutine "proved" by calling other subhypotheses (bird, mammal, and so on), also in the form of subroutines, that in turn call still other hypothesis/subroutines (has feathers, lays eggs, and so on). If you could call such procedures recursively (which is not required in this kind of system), then you would have a recursive descent parser—not exactly what you would call quick-and-dirty code.

Such syntax-directed recognizers are not general purpose—meaning that you cannot simply plug in a new set of rules describing expertise in some other domain of knowledge—but they are faster than general-purpose inference engines and they are more in keeping with the procedural and modular knowledge representation philosophy suggested by production rule systems. Indeed, you can now insert additional, special subroutines or functions of arbitrary complexity here and there in the program as needed. Such systems allow the BASIC language to do what it does best—define the heuristic flow of control (procedures) of the expert

system. It does this so well that you can no longer refer to the production rules explicitly because they are now implied in the pattern of nested subroutines residing in the code. You must therefore now speak not just of rules and combined assertions but of "facts" and "combined facts" in numeric arrays worked upon by the subroutines, all of which can be imagined as residing on the nodes and arcs of an imaginary inference net or AND/OR tree.

Another strength of this kind of system is that error messages and explanations of the top-down reasoning process are easier to program as the system is designed specifically for the particular knowledge base used.

Like MYCIN, the system presented here can accept information volunteered by users at any level of the reasoning process. If users are not absolutely sure of the animal or classification they are thinking of, the program ignores their input and digs deeper into the AND/OR tree. Provision has been made in the program for programmers to change this threshold easily (see the *IF* statement two lines above the *Test.for.a.positive.number*: subroutine).

AND Clauses

The system can handle negative inferences and degrees of certainty in a user's answers through a mathematical process essentially the same as that used by MYCIN.

```
procedure STATEMENT;
  local LEXEME;
  LEXEME=GETLEXEME;
  select LEXEME of
    "LET":      begin
                  call IDENTIFIER;
                  IF GETLEXEME /= "=" then call ERROR;
                  call EXPRESSION;
                end;
    "NEXT":     call IDENTIFIER
    "INPUT":    call IDENTIFIERLIST;
    "GOTO":     call LINENUMBER;
    "FOR":      begin
                  call IDENTIFIER;
                  if GETLEXEME /= "=" then call ERROR;
                  call EXPRESSION;
                  if GETLEXEME /= "TO" then call ERROR;
                  call EXPRESSION;
                end;
    "GOSUB":    Call LINENUMBER;
  end;
```

Example 1: John Zarrella's syntax recognizer

As an example, let's take a look at one of the rules in the system's AND/OR tree:

IF animal is an UNGULATE
AND animal HAS BLACK STRIPES
THEN animal is a ZEBRA
(attenuation factor=0.8)

Let's say that the user's certainty on the *UNGULATE* branch of the *ANDed* relation is 0.7 (1.0 being absolute certainty) and the certainty on the *HAS BLACK STRIPES* branch is 0.8.

In normal probability theory, you would multiply the individual fractional probabilities, yielding 0.56. MYCIN, however, does not use standard probability theory. Conventional probability theory was rejected because it was felt that the *AND* clauses in classification systems violate the two foundations of standard probability theory (particularly Bayes' rule): statistical independence and prior probabilities (or priors).

Standard statistical probability assumes that the components in the *ANDed* relations are independent of each other and that an examination of a sufficiently large number of examples of a rule allows you to construct a statistical, frequency model of the rule so that you can give an a priori probability of a hypothesis being true in the absence of any evidence. The developers of MYCIN rejected and/or modified these ideas because the symptoms of a disease (or the physical attributes of an animal, for that matter) are not independent but usually occur in groups. Also, it is difficult to obtain data on and analyze thousands of cases to determine frequencies.

Instead, MYCIN's developers created their own technique for dealing with uncertainty, based on confirmation theory (logical probability) and the use of certainty factors and attenuation factors. You must therefore distinguish certainty (the degree of confidence you have in a fact or rule) from ordinary probability.

A certainty factor (CF) is a number between -1 and 1 given to a fact or relation to indicate the confidence a user has in providing data concerning a fact or relation to the expert system. In this sense, certainty factors

are really confidence factors, not probability coefficients. By the end of a user's session with an expert system, the program itself has combined and computed new certainty factors. In MYCIN, if the computed truth of a fact exceeds 0.8, then the fact is judged to be proven and the certainty factor is now 1.0. Also, if the certainty factor falls into the range -0.2 to 0.2, then the certainty factor is set to 0 (unknown) and a certainty factor in the range -0.8 to -1.0 is converted to -1.0 (definitely false).

The program combines and computes new certainty factors.

An attenuation factor is a number between 0 and 1 that is multiplied by a certainty factor, yielding a new certainty factor. It is an indicator of a rule's inherent reliability, or at least the confidence a human expert had in the efficacy of the rule when the system was being developed. Just as a certainty factor starts out as really a confidence factor on the part of the user, an attenuation factor is likewise a confidence factor on the part of the human expert from whom the rules were derived.

In the *AND* clause shown earlier, the probability of one conditional *AND* another is taken as a minimum of their certainties, so the program finds the lowest certainty factor on the branches of the *AND* clause (the certainty factors of *UNGULATE* or *HAS BLACK STRIPES*) and multiplies it by the attenuation factor of 0.8. If the certainty passed up the tree by the *Prove.ungulate*: subroutine is 0.7 and the certainty factor given by the *Prove.black.stripes*: subroutine is 0.8, the *Prove.zebra*: subroutine will select the lower figure of 0.7 and multiply it by the zebra *AND* clause attenuation of 0.8, yielding a new output certainty factor of 0.56. The figure, coincidentally, matches that given by

standard probability. In any event, this result is passed up to the user as the final certainty factor for the animal being a zebra.

OR Clauses

But what would have been the case if the rule had been an *OR* clause instead of an *AND* clause? That is, what if the rule had looked like this:

IF animal is an UNGULATE
OR animal HAS BLACK STRIPES
THEN animal is a ZEBRA

The designers of MYCIN thought that the certainty factors on the branches of an *OR* node should reinforce one another. Remember that the certainty factor on the *UNGULATE* branch is currently 0.7 and the certainty factor on the *HAS BLACK STRIPES* branch is 0.8. The CF on the *UNGULATE* branch takes you 70 percent toward proving that the animal is a zebra (0.7). That still leaves 30 percent (0.3) to go in order to achieve absolute certainty. As it happens, the CF on the *HAS BLACK STRIPES* branch (0.8) "carries" the total certainty an additional 80 percent over the remaining distance of 0.3. Because 80 percent of 0.3 is 0.24, the certainty factor of the animal being a zebra is now 0.7 + 0.24, or 0.94. Had a third branch existed with a certainty factor of, say, 0.5, then the total certainty would have been carried another 50 percent over the remaining distance of 0.06, yielding a new total certainty factor of 0.97.

One way of expressing this procedure mathematically is as follows:

$$\text{New CF} = \text{CF1} + \text{CF2}(1 - \text{CF1})$$

A more confusing (though equivalent) expression is this one:

$$\text{New CF} = \text{CF1} + \text{CF2} - (\text{CF1} \times \text{CF2})$$

In order to handle negative numbers, however, you would have to convert the above equation into the following:

$$\text{New CF} = \text{CF1} + \text{CF2} + (\text{CF1} \times \text{CF2})$$

Also, things get awkward when you are using three certainty factors:

$$\text{New CF} = \text{CF1} + \text{CF2}(1 - \text{CF1})$$

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EXPERT SYSTEMS

(continued from page 44)

$$+ CF3(1 - [CF1 \\ + CF2(1 - CF1)])$$

Fortunately, this equation can be simplified to this one:

$$\text{New CF} = 1 - (1 - CF1)(1 - CF2) \\ (1 - CF3)$$

My system uses this equation if at least one certainty factor on a branch is positive. If all the certainty factors are negative or 0, the system uses this

equation:

$$\text{New CF} = -1 + (1 + CF1)(1 + CF2) \\ (1 + CF3)$$

At this point you should distinguish the use of negative numbers in stating the confidence in a hypothesis from situations where a lack of evidence is necessary to prove a hypothesis, in which case you must add a rule to the knowledge base testing for the lack of certain information. Here is one such rule from MYCIN itself:

IF identity of organism

is not known

AND gram stain of organism

is not known

AND morphology of organism
is not known

AND site of culture is csf

AND infection is meningitis

AND age of patient

is less than or equal to 17

THEN (.3) category of organism
is enterobacteriaceae.

Some researchers have pointed out some deficiencies with the MYCIN approach to reasoning with certainty factors.⁴ I find that all forms of the OR clause equations increase the certainty factor values too much, so I place attenuations on all possible branches to bring the results closer to what you would expect from standard probability theory. Researchers now use formulas closer to standard probability theory in the new systems, but I will not examine them here.

Expanding the System

The system is currently designed to identify seven animals, and the *HYPOTHESIS* numeric array has been dimensioned to accept up to 20 animals. I'll now demonstrate how you add a new animal to the system.

Let's say you want the program to be able to recognize an emu, which is a large flightless bird like an ostrich but with dark feathers and large red eyes. The rule you wish to express is as follows:

IF the animal is a BIRD

AND the animal CANNOT FLY

AND the animal HAS DARK FEATHERS

AND the animal HAS BIG RED EYES

THEN the animal is an EMU

This AND clause looks as if its going to be pretty reliable, so let's give it an attenuation of 1.

Remember that, as the program is backward chaining, it looks at this rule in reverse, taking the emu identity as a hypothesis to be proved by calling other subroutines that in turn attempt to prove that the animal is a bird, cannot fly, and so on.

Let's add the actual emu subroutine first. First, you scroll down to the bottom of the *DATA* statements, where you see the following lines:

DATA 35,has pointed teeth

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```
pointed.teeth=35
DATA -1, END OF DATA
```

Now add the new fact and user request string for *emu* (fact #36) above the last line. The result should look like this:

```
DATA 35,has pointed teeth
pointed.teeth=35
DATA 36,is an emu
emu=36
DATA -1, END OF DATA
```

As *emu* is one of the top-level hypotheses (animals to be identified), there are two special areas in the program to change. Below the line, *REM TOP-LEVEL HYPOTHESES (ROOTS) OF AND/ OR TREE*;, find these lines:

```
HYPOTHESIS(7)=cheetah
number.of.hypotheses=7
```

and change them to look like these:

```
HYPOTHESIS(7)=cheetah
HYPOTHESIS(8)=emu
number.of.hypotheses=8
```

The other area of the program to change as a result of *emu* being a top-level hypothesis is the executive calling routine a little farther down. Make an addition just above line 10165 that reads as follows:

```
GOSUB Prove.emu
IF halt.on.success=2
  AND OUTPUT.CF(emu)=1 THEN 10165
```

You then add the subroutine shown in Example 2, below, to prove

the animal is an emu (with an attenuation of 1) to the very bottom of the program.

If you had been trying to represent an *OR* clause instead of an *AND* clause:

```
IF the animal is a BIRD
OR the animal CANNOT FLY
OR the animal HAS DARK FEATHERS
OR the animal HAS BIG RED EYES
THEN the animal is an EMU
```

you would have had to assign attenuations to each branch because the components of such a disjunctive relation can each be considered as a separate minirule contributing a certainty factor to prove that the animal is an emu. This is known as a multiply argued certainty. A subroutine describing this (again with arbitrarily chosen attenuations) would look like that in Example 3, page 48.

But what if the rule had taken the form of a compound relationship of *ANDs* and *ORs*?

```
IF (animal is a BIRD
  AND animal CANNOT FLY
  AND animal HAS DARK FEATHERS)
OR animal HAS BIG RED EYES
THEN animal is an EMU
```

This way of proving the animal is an emu is actually just an *OR* clause with two components, one of which can be further reduced to some *ANDs*. My solution is to write a separate routine for the *AND* clause (with an additional attenuation to keep the *OR* clause certainty under control). Thus, you now have the two subroutines

```
Prove.emu:
  current.fact=emu
  GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.bird
  GOSUB Prove.cannot.fly
  GOSUB Prove.dark.feathers
  GOSUB Prove.big.red.eyes
  number.of.and.clause.components=4
  AND.COMPONENT(1)=bird
  AND.COMPONENT(2)=cannot.fly
  AND.COMPONENT(3)=dark.feathers
  AND.COMPONENT(4)=big.red.eyes
  at.factor.for.AND.clause=1
  GOSUB Compute.AND.clause.cf
  GOSUB Deduce
  RETURN
```

Example 2: Emu-proving subroutine

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EXPERT SYSTEMS (continued from page 47)

shown in Example 4, below.

Supposedly, the Amiga BASIC interpreter does not accept subroutine labels longer than 40 characters, but the 43-character label *Prove.bird.and.cannot.fly.and.dark.feathers* works correctly. The Microsoft people probably mean that the first 40

characters of the label are significant.

The second subroutine will also require access to both the user and the numeric arrays to compute the certainty factors, so you must log it in your *DATA* statements:

```
DATA 37, is a bird and cannot fly
      and dark feathers
bird.and.cannot.fly
      and.dark.feathers=37
```

```
Prove.emu:
  current.fact=emu
  GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.bird
  GOSUB Prove.cannot.fly
  GOSUB Prove.dark.feathers
  GOSUB Prove.big.red.eyes
  number.of.or.clause.components=4
  OR.COMPONENT(1)=bird
  AT.FACTOR.FOR.OR.COMPONENT(1)=.8
  OR.COMPONENT(2)=cannot.fly
  AT.FACTOR.FOR.OR.COMPONENT(2)=.85
  OR.COMPONENT(3)=dark.feathers
  AT.FACTOR.FOR.OR.COMPONENT(3)=.9
  FOR.COMPONENT(4)=big.red.eyes
  AT.FACTOR.FOR.OR.COMPONENT(4)=1
  GOSUB Compute.or.clause.cf
  GOSUB Deduce
  RETURN
```

Example 3: Alternate emu-proving subroutine

```
Prove.emu:
  current.fact=emu
  GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.bird.and.cannot.fly.and.dark.feathers
  GOSUB Prove.big.red.eyes
  number.of.or.clause.components=2
  OR.COMPONENT(1)=bird.and.cannot.fly.and.dark.feathers
  AT.FACTOR.FOR.OR.COMPONENT(1)=.8
  OR.COMPONENT(2)=big.red.eyes
  AT.FACTOR.FOR.OR.COMPONENT(2)=.85
  GOSUB Compute.or.clause.cf
  GOSUB Deduce
  RETURN

Prove.bird.and.cannot.fly.and.dark.feathers:
  current.fact=bird.and.cannot.fly.and.dark.feathers
  GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.bird
  GOSUB Prove.cannot.fly
  GOSUB Prove.dark.feathers
  number.of.and.clause.components=3
  AND.COMPONENT(1)=bird
  AND.COMPONENT(2)=cannot.fly
  AND.COMPONENT(3)=dark.feathers
  at.factor.for.and.clause=1
  GOSUB Compute.and.clause.cf
  GOSUB Deduce
  RETURN
```

Example 4: Emu-proving routines for compound case

So much for the emu subroutine.

As for the other subroutines that *Prove.emu*: calls, you already have those that attempt to prove that the animal is a bird and cannot fly, but you need two subroutines to prove that the animal has dark feathers and big red eyes. These are both terminals (they don't have to call other parsing subroutines—they just ask the user a question), so they are easier to write. First, you add this new set of *DATA* statements near the top:

```
DATA 38,has dark feathers
dark.feathers=38
```

```
DATA 39,has big red eyes
big.red.eyes=39
```

Having done this, you scroll to the bottom of the program and add two subroutines:

```
Prove.dark.feathers:
  current.fact=dark.feathers
  GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN
```

```
Prove.big.red.eyes:
  current.fact=big.red.eyes
  GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN
```

That's it.

By writing some templates of various sizes for the subroutines handling *ANDs* and *ORs*, you can copy them as needed and quickly assemble a MYCIN-like expert system running under the Amiga BASIC (Microsoft BASIC) interpreter. The system currently can handle rules with clauses having 12 *ANDs*, 12 *ORs*, or a combination of both. You can change this easily by redimensioning the *AND.COMPONENT*, *OR.COMPONENT*, and *AT.FACTOR.FOR.OR.COMPONENT* arrays.

You might experiment by inserting additional subroutines that perform other mathematical tests outside the MYCIN environment (go ahead, it's OK—most mathematicians think MYCIN's mathematical reasoning is pretty ad hoc anyway, even though it has been known to outperform experts, which isn't saying much for experts!). You might also consider add-

ing subroutines allowing the program to explain how a certainty factor was reached after the conclusion of each fact by listing the certainty factors passed up from those below it in the *AND/OR* hierarchy.

Long names have been used to identify the subroutines and variables only in an effort to make the program's flow of control understandable. By shortening these considerably, you should be able to fit hundreds of rules in an Amiga with 512K of memory. Alternatively, Amiga BASIC allows you to set up deductive routines as separate pro-

grams that can be called as overlays when needed by the top-level routines, then deleted. The only precondition is that a called program has to be saved as an ASCII file (*SAVE "file-spec",A*) or else a "bad file mode" error message appears.

You can call a secondary program with:

```
CHAIN MERGE "filespec",
[expression],ALL,DELETE range
```

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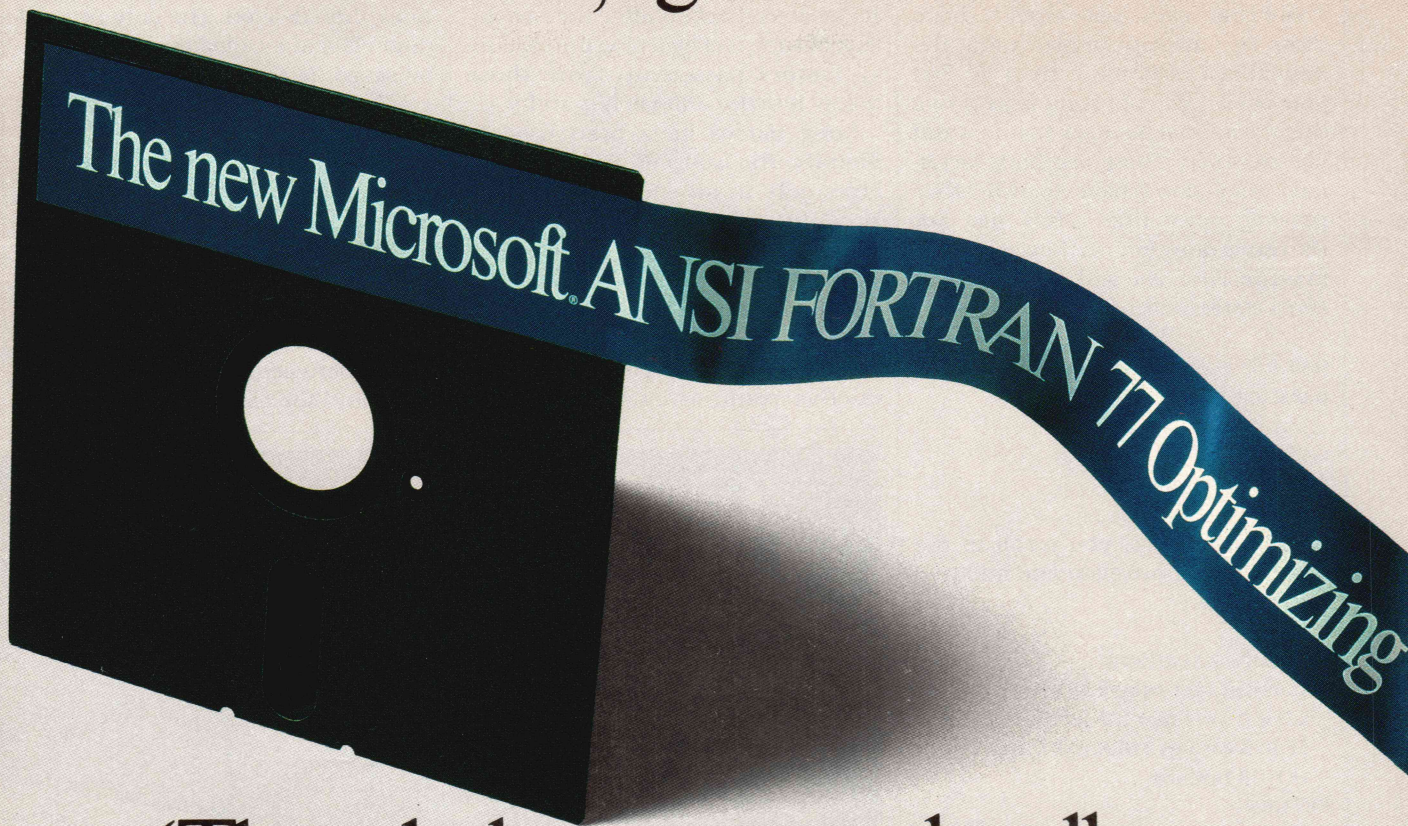
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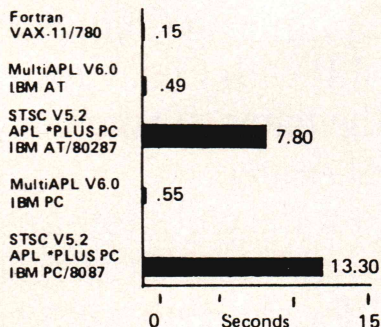
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(continued from page 49)

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Notes

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2. Richard O. Duda and John G. Gaschnig, "Knowledge-Based Expert Systems Come of Age," *Byte*, vol. 6 no. 9 (September 1981): 238-281.
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```

```
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 *      (An Experimental Computer Vision Program)
 *
 *      This program implements a trainable pattern classifier as
 *      a committee network of threshold logic units. It learns to
 *      recognize patterns by being trained from a set of prototype
 *      patterns presented in a training file. The training file is
 *      organized as a set of visual images represented as an orthogonal
 *      array of picture elements, or pixels. Each pixel is a number
 *      representing the gray-scale value of that point in the image.
 *      Associated with each pattern is a number, or tag, that
 *      represents the category to which that pattern belongs.
 *
 *      R. J. Brown
 *      Elijah Laboratories International
 *      5225 N.W. 27th Court
 *      Margate, FL 33063
 *      (305) 979-1567
 *
 *      Ownership: I hereby place this program in the public domain.
 *
 *      System:   Red River Atlas 10 MHz 80286 IBM-PC/AT clone
 *
 *      Compiler: C86 Version 2.30H; Computer Innovations, Inc.
 */

#include "stdio.h"          /* needed for stream input/output */

#define FALSE      0        /* boolean constant for 'false' */
#define TRUE       !FALSE   /* boolean constant for 'true' */

#define NULL ((int *)0)    /* the pointer to nowhere */

#define void       /* function that returns no value */

#define forall(index,limit)\
    for((index)=0;(index)<(limit);(index)++) /* looping word */

#define kase(id,stmt) \
    case(id): { \
        stmt; \
        break; \
    } /* shorthand form for case statement */

#define u(x) ((unsigned)(x)) /* shorthand for '(unsigned)' cast */

typedef unsigned char  byte; /* an 8-bit byte of storage */
typedef unsigned int   word; /* a 16-bit word of storage */

typedef word           boolean; /* a decision variable,
 * 'true' or 'false value only */

typedef ELTYPE        element; /* an element is a real number */
typedef DOTYPE        DOT;     /* type of a dot product may be bigger! */
typedef element        *vector; /* a vector is a set of elements */

typedef vector         tlu;     /* a tlu is a vector */

typedef struct {             /* the collection of */
    tlu      *wtpt;          /* a set of tlu weight points, */
    DOT      *dot;           /* and dot product save cells */
} committee;               /* is a committee */

typedef char          *pointer; /* a general pointer to whatever... */

/*****
 *
 *      Global Variable Definitions
 *
 *****/

FILE      *pat,              /* the input training pattern file */
          *fopen();          /* the file opener */
byte      patname[64],       /* ascii filename of input file */
          *index();          /* string search library function */
```



```

int      ncom,           /* number of committees in the network */
         patwide,        /* pattern width in pixels */
         pathite,        /* pattern height in pixels */
         pats_so_far,    /* how many patterns in file so far */
         pats_missed,    /* how many patterns were mis-recognized so far */
         missed,         /* # of patterns missed on this pass */
         tlu_trained,    /* how many tlu's have been adjusted so far */
         npass,          /* number of current pass thru pattern file */
         log_level,      /* level of detail for run-time logging */
         dim,            /* number of elements in a vector (dimension) */
         ntl,           /* number of tlu per committee */
         corr_incr,      /* fixed increment correction constant */
         *vote;          /* pointer to vote count array */

boolean goofed,          /* mis-recognition indicator for training loop */
        start_over,     /* select start over on error training strategy */
        absolute,       /* flag for absolute correction training method */
        *decsn,         /* pointer to network's decision array */
        *class;         /* pointer to class (category) array */

DOT      patmag;         /* pattern magnitude (used for training) */

element fraction,        /* correction fraction for training */
        maxel=0;         /* maximum element in a weight point */
        radius;          /* average radius (distance from origin)
                        * of tlu weight point at initialization */

vector pattern;          /* pointer to current input pattern */

committee *net;          /* pointer to network as an array of committees */

/*****
 *
 *      L i b r a r y   R o u t i n e s
 *
 *****/

extern float atof(); /* ascii to float library conversion routine */
extern double sqrt(); /* square root library function */
extern pointer calloc(); /* memory allocation library function */
extern long time(); /* benchmark timing routine */

/*****
 *
 *      B A N N E R  --  D i s p l a y   P r o g r a m   I . D .
 *
 *****/

void banner() { /* display program identification information */

    printf("\n%s",PGM_ID); /* Program Identification is #define'd
                        * at top of source file */

    printf("\nWritten by: R. J. Brown, Elijah Laboratories Intn'l");
    printf("\nThis program is in the Public Domain.\n");
}

/*****
 *
 *      H E L P   D i s p l a y   S c r e e n
 *
 *****/

void help() { /* some user friendly help for the uninitiated */

    printf("Simple Image Learning On Adaptive Machinery\n");
    printf("An Adaptive Template Matching Image Categorizer\n");
    printf("\n");
    printf("R. J. Brown, Elijah Laboratories International\n");
    printf("5150 W. Copans Rd. Suite 1135, Margate FL 33063\n");
    printf("\n");
    printf("usage:      siloam <options> filename[.ext]\n");
    printf("where: filename -- is the input pattern file.\n");
    printf("options: -r##.# -- gives initialization radius.\n");
    printf("          -t## -- gives number of TLUs per committee.\n");
    printf("          -o -- start over on error.\n");
    printf("choose one: -i## -- fixed increment correction, ## = incr.\n");
    printf("          -a -- absolute correction.\n");

```

(continued on next page)

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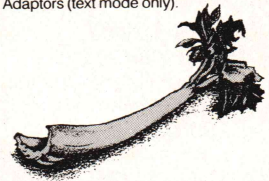
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NEURAL NETWORK

Listing One (Listing continued, text begins on page 16.)

```
printf("          -f##.# -- fractional correction, ##.# is lambda.\n");
printf("          -l# -- logging level: 0=least; 3=most.\n");
exit(0);
}

/*****
 *
 *      S I G N -- The Sign Of An Element +/- 1
 *
 *****/

int sign(x)      /* return the sign of a number as plus or minus one */
element x;      /* argument is an element */
{
    return( x<(element)0 ? -1 /* if number is negative, return -1 */
           : 1 );/* else return +1 */
}

/*****
 *
 *      I S I G N -- The Sign Of An Integer +/- 1
 *
 *****/

int isign(x)     /* return the sign of a number as plus or minus one */
int x;          /* argument is an integer */
{
    return( x<0 ? -1 /* if number is negative, return -1 */
           : 1 );/* else return +1 */
}

/*****
 *
 *      A B S -- Absolute Value Of An Element
 *
 *****/

element eabs(x)  /* the absolute value of an element */
element x;      /* argument is an element */
{
    return( x<0 ? -x /* if number is negative, make it positive */
           : x );/* else return it like it is */
}

/*****
 *
 *      I A B S -- Absolute Value Of An Integer
 *
 *****/

int iabs(x)      /* the absolute value of an integer */
int x;          /* argument is an integer */
{
    return( x<0 ? -x /* if number is negative, make it positive */
           : x );/* else return it like it is */
}

/*****
 *
 *      A L P H A -- Step Function
 *
 *****/

int alpha(x)     /* step function return zero or one */
int x;          /* argument is an integer (in this program...) */
{
    return( x>0 ? 1 /* if argument strictly positive, return one */
           : 0 );/* else return zero */
}

/*****
 *
 *      M O V E -- String Move Function
 *
 *****/
```

(continued on page 60)

SAS Institute Inc. Announces

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- **Optimization of the generated code.** We know the 370 instruction set and the various 370 operating environments. We have over 100 staff years of assembler language systems experience on our development team.
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NEURAL NETWORK

Listing One (Listing continued, text begins on page 16.)

```
char *move(src,dst)      /* move a string returning ptr to end of result */
char *src,*dst;          /* pointers to source & destination strings */
{
    while(0!==( *dst++=(*src++) )); /* copy bytes until end of source */
    return(--dst);          /* return ptr to end of destination */
}

/*****
 *
 *   R A D I U S   S T A T I S T I C S   --   S u m m a r y   I n f o
 *
 *****/

void radius_statistics() { /* show how weight points are distributed */

    element r,          /* current radius accumulator */
    *pe;               /* pointer to current element */
    float mu=0,         /* mean of radii */
    sigma=0;           /* standard deviation of radii */

    committee *pc=net; /* pointer to current committee */

    vector *pt;         /* pointer to current tlu */

    int c,              /* committee loop counter */
    t,                 /* tlu loop counter */
    e,                 /* element loop counter */
    n=com*ntlu;        /* number of tlu's altogether */

    forall(c,ncom) { /* for all committees... */
        pt=pc++->wtpt; /* point to first tlu */
        forall(t,ntlu) { /* for all tlu's... */
            pe=*pt++; /* point to first element */
            r=0.; /* initialize radius tally */
            forall(e,dim) { /* for all elements... */
                r+=( *pe ) * ( *pe ); /* accumulate radius sqr'd */
                pe++; /* point to next element */
            }
            mu+=sqrt((float)r); /* accumulate sum of radii */
            sigma+=(float)r; /* accumulate variance variable */
        }
    }

    mu/=(float)n; /* divide to get overall average radius */
    sigma-=mu*mu*n; /* compute variance */
    sigma=sqrt(sigma)/mu; /* compute standard deviation */

    printf("\nmean of the radii: %f",mu); /* print statistical */
    printf("\nstandard deviation: %f",sigma); /* summary of weight */
    printf("\n"); /* point distribution */

}

/*****
 *
 *   R E A D   H E A D E R   --   R e a d   F i l e   H e a d e r
 *
 *****/

void read_header() /* read training file header information */
{
    rewind(pat); /* rewind pattern file */
    pats_so_far=0; /* reset pattern sequence counter */

    fscanf(pat, /* header comes from pattern file */

        "hdr %d %d %d \n", /* header must start with 'hdr'
                             * then read header information
                             * composed of three numbers */

        /* put this information into the following global variables */

        &ncom, /* number of committees in network */
        &patwide, /* pattern width in pixels */
        &pathite); /* pattern height in pixels */
}
```

(continued on page 65)

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NEURAL NETWORK

Listing One (Listing continued, text begins on page 16.)

```

/*****
 *
 *  RANDOM  --  Random  Number  Generator
 *
 *****/

element random() {      /* generate a uniformly distributed
                        * random number from the open interval (0...1) */

    return(rand()/16384.);    /* return scaled random integer */
}

/*****
 *
 *  INIT  VAL  --  Initial  Element  Value
 *
 *****/

element init_val(radius) /* generate init'l value for element a tlu */
element radius;          /* the average radius of a weight point */
{

    return(
        (radius*sqrt(3.))/(sqrt((float)dim)) /* average weight value */
        * (2.*random()-1) /* scaled randomly by a */
    ); /* uniform distribution */
}

/*****
 *
 *  INITIALIZE  --  Allocate  Storage,  Etc.
 *
 *****/

void initialize() { /* allocate & initialize network array storage */

    committee *pc; /* pointer to current committee of network */
    tlu *pt; /* pointer to current tlu of committee */
    element *pe, /* pointer to current element of tlu */
    x; /* current initialization weight value */

    int c, /* committee index in network */
    t, /* tlu index in committee */
    e; /* element index in tlu */

    printf("\ninitializing"); /* say what's taking so long ! */

    dim=patwide*pathite+1; /* number of elements in a tlu */

    pattern=(vector) calloc(u(dim), /* allocate the pattern */
        u(sizeof(element))); /* vector */

    class=(boolean *) calloc(u(ncom), /* allocate the class array */
        u(sizeof(boolean))); /* which will contain the
    * desired decision bits from the committees, as read from the
    * training file. the actual verdict of the network will be
    * compared with this to see if training is required. */

    vote=(int *) calloc(u(ncom), /* allocate the votes array */
        u(sizeof(int))); /* which will contain the
    * count of votes for each
    * committee. */

    decsn=(boolean *) calloc(u(ncom), /* allocate the decision */
        u(sizeof(boolean))); /* array which will contain
    * the bits of the answer,
    * one bit per committee. */

    pc=net=(committee *) calloc(u(ncom), /* allocate the network */
        u(sizeof(committee))); /* as an array of committees */

    forall(c,ncom) { /* for all committees in the network... */

        pc->wtpt=pt=(tlu *) calloc(u(ntlu), /* allocate a committee */
            u(sizeof(tlu))); /* as an array of tlu's */

        pc++->dot=(DOTYPE *) calloc(u(ntlu), /* together with dot */
            u(sizeof(DOT))); /* product save cells */

        forall(t,ntlu) { /* for all tlu's in the committee... */

```

(continued on next page)

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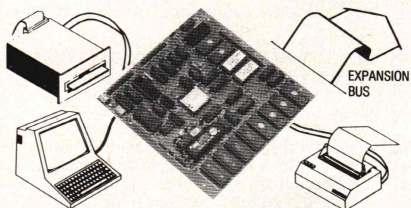
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NEURAL NETWORK

Listing One (Listing continued, text begins on page 16.)

```

pe=*pt++=(element *)calloc(u(dim),      /* allocate a tlu */
                           u(sizeof(element))); /* as an array
                                                * of elements */

forall(e,dim) {                          /* for each weight... */
    if(radius==0) *pe++=(e!=0);          /* grow connections? */
    else {                                /* or adjust weights? */
        x=eabs(*pe++=init_val(           /* adjust, get initial */
                           (element)radius)); /* weight value */
        if(x>maxel) maxel=x;             /* update max magnitude */
    }
}

/* initialize each element to a random value such that the average
 * radius, or distance from the origin, of each weight point is 'radius'.
 * this will produce a distribution of weight points clustered near the
 * surface of a hyper-sphere as the starting condition. If the radius is
 * zero, then all weights will be set to zero except for the threshold
 * setting weight. This is analogous to forcing the program to grow new
 * interneural connections on an as-needed basis, supposedly just like
 * the real brain does! */
}

printf("\n"); /* perform new-line when initialize is done */
}

/*****
 *      DOTPROD -- Form A Dot Product
 *****/

DOT dotprod(x,y) /* form the scalar product of two vectors */
vector x,y;      /* both arguments are vectors */
{
    DOT z=0;      /* result accumulator, initialized to zero */
    int i;        /* element index, used as loop counter */

    forall(i,dim) /* for all elements in each vector... */
        z+=(*x++)*(*y++); /* compute the dot product */

    return(z);    /* return it to the caller */
}

/*****
 *      READ CLASS -- Read The Class Tag
 *****/

boolean read_class() { /* read the class tag number for the image */

    int i,          /* loop counter for index in class array */
        tmp;       /* temp cell to hold decimal category */
    boolean *pcl=class; /* pointer to class (category) array */

    if(fscanf(pat,"%d",&tmp)!=1) /* read the pattern category */
        return(FALSE);          /* return FALSE for end of file */

    forall(i,ncom) {             /* for each committee in network */
        *pcl+=tmp&1;             /* extract desired committee output */
        tmp>>=1;                 /* advance to next committee */
    }

    *pcl=1;                      /* augment with a 1 to prevent singularity */
    pats_so_far++;               /* update pattern sequence counter */

    return(TRUE);               /* return TRUE if class read successfully */
}

/*****
 *      READ PATTERN -- Read Next Pattern
 *****/

boolean read_pattern() { /* read next pattern from training file */

    int i,j;              /* loop counters for row & column of image */
    element *pe=pattern; /* pointer to element of pattern vector */
    float tmp;            /* temp cell for input conversion */

```



```

forall(i,patwide)          /* for each row in the image, */
  forall(j,pathite)        /* for each pixel in that row, */
    if( fscanf(pat,"%f",&tmp) /* input value of pixel */
        !=1) return(FALSE); /* return FALSE if end-of-file */
    else *pe++=(element)tmp; /* convert to type element */

return( read_class() ); /* read in its class as an array
 * of correct decisions for each committee in the network. If the
 * entire pattern is read, together with its class, return TRUE. */
}

/*****
 *
 *      COUNT VOTES -- Count The Votes
 *
 *****/

int count_votes(pc) /* count the votes for each tlu in a committee */
committee *pc; /* second parameter is a pointer to committee */
{
  DOT *pd=pc->dot; /* dot product save cell pointer */
  tlu *pt=pc->wtpt; /* tlu pointer */

  int ti, /* tlu index (loop counter) */
      count=0; /* the count of votes for the committee */

  forall(ti,ntlu) /* forall tlus in committee */
    count+=sign( /* count votes as + or - */
      *pd++; /* & save dot product as */
      dotprod(*pt++,pattern) /* weight point dotted with */
    ); /* pattern vector */
  return(count); /* return tally */
}

/*****
 *
 *      RECOGNIZE -- Recognize A Pattern
 *
 *****/

void recognize() { /* recognize a pattern by taking the decision
 * of each committee to be a bit in the category
 * number for the pattern
 */

  int i, /* loop counter */
      *pv=vote; /* pointer to vote count array */

  boolean *pdec=decsn; /* pointer to decision array.
 * this holds the decision bits for each
 * of the committees in the network.
 */

  committee *pc=net; /* pointer to current committee in network */

  forall(i,ncom) /* for all committees in the network... */
    *pdec++=alpha(*pv++=count_votes(pc++)); /* how many votes ? */
}

/*****
 *
 *      $ GET WEAK TLU -- Sway Which One ?
 *
 *****/

int get_weak_tlu(ci) /* choose tlu most vulnerable to be swayed */
int ci; /* argument is committee index */
{
  int weak=0, /* index of weakest tlu so far */
      sv=sign(vote[ci]), /* sign of committee's vote */
      ti; /* tlu index */

  DOT *pd=(net[ci]->dot, /* pointer to dot product array */
conviction=INFINITY, /* lowest conviction so far */
d; /* saved dot product value */

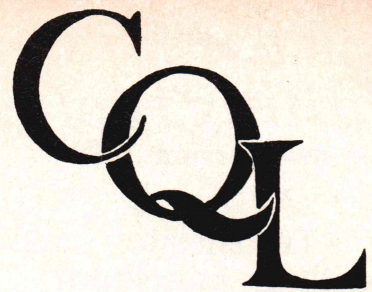
  forall(ti,ntlu) { /* for all of the tlu's in this committee... */

    d=pd[ti]; /* get the saved dot product value */

    if(sign(d)==sv) { /* if tlu voted incorrectly */

```

(continued on next page)



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NEURAL NETWORK

Listing One (Listing continued, text begins on page 16.)

```
if(eabs(d)<conviction) { /* and if this tlu has the
    * least conviction of any that have been examined so far, */

    weak=ti; /* then remember it as the best one so
    * far to adjust to sway the vote of this committee. */

    conviction=eabs(d); /* update lowest conviction */
}
}
return(weak); /* return subscript of weakest tlu in committee */
}

/*****
 *
 * ADJUSTMENT -- Correction Coefficient
 *
 *****/

element adjustment(ci,ti) /* compute correction coefficient */
int ci, /* committee index */
ti; /* tlu index */
{
    DOT d=(&net[ci])->dot[ti]; /* saved dot product */

    if(corr_incr) /* fixed increment correction */
        return(corr_incr*sign(d));

    if(absolute) /* absolute correction */
        return((int) (d/patmag)+sign(d));

    if(fraction) /* fractional correction */
        return(d*fraction/patmag);

    return(abort("No correction method specified."));
}

/*****
 *
 * ADJUST -- Change TLU's Weights
 *
 *****/

void adjust(ci,ti) /* adjust the weights of a single tlu */
int ci, /* committee index */
ti; /* tlu index */
{
    vector pw=(&net[ci])->wtpt[ti], /* pointer to a weight */
    pp=pattern; /* pointer to a pixel */

    element lambda=adjustment(ci,ti), /* the correction coefficient */
    wt,awt; /* temps for max weight point */

    int i; /* element index & loop counter */

    tlu_trained++; /* count adjustment of tlu */

    forall(i,dim) { /* for each coefficient */
        wt=(*pw++)-=lambda*(*pp++); /* adjust weights */
        awt=eabs(wt); /* save magnitude */
        if(maxel<awt) { /* new maximum ??? */
            maxel=awt; /* yes, update max elem */
            if(log_level) { /* if any logging, */
                printf("\nmaxel=%f", /* then display the */
                    (float)maxel); /* new maximum value */
            }
        }
    }

    if(log_level>=3)
        printf("\n com=%d tlu=%d lambda=%g",
            ci,ti,(float)lambda);
}

/*****
 *
 * SWAY TLUS -- Sway TLUS To Change Vote
 *
 *****/
```



```

void sway_tlus(ci) /* sway enough tlu's to change the vote */
int ci; /* parameter is committee index */
{
    int i, /* loop counter */
        lost_by=iabs(vote[ci]/2)+1, /* how many votes we lost by */
        weak_tlu; /* weakest wrong tlu in committee */

    DOT *pd=(&net[ci])->dot; /* pointer to dot product array */

    forall(i,lost_by) { /* do this enough times to sway the vote... */

        weak_tlu=get_weak_tlu(ci); /* find most vulnerable tlu */

        adjust(ci,weak_tlu); /* adjust its weights to change
                               * its mind about the pattern */
        pd[weak_tlu]=--sign(pd[weak_tlu]); /* flip sign of dot product
        * so this tlu won't be considered again in this loop */
    }
}

/*****
 *
 * SHOW BITS -- Display Bits On CRT
 *
 *****/

void show_bits(ps,pb) /* display a bit vector on the screen */
char *ps; /* the label for the bit vector */
boolean *pb; /* the pointer to the bit vector */
{
    int i, /* loop counter */
        k=1, /* power of two */
        v=0; /* value accumulator */

    forall(i,ncom) { /* for all committees */
        if(*pb++) v+=k; /* convert binary to decimal */
        k<<=1; /* advance to next bit */
    }
    printf(" %s %d",ps,v); /* display label and value */
}

/*****
 *
 * TRAIN -- Train The Network
 *
 *****/

train() { /* train the network to recognize the pattern */

    int ci; /* committee index */

    goofed=FALSE; /* give benefit of doubt -- assume didn't goof */

    patmag=dotprod(pattern,pattern); /* find pattern magnitude */

    forall(ci,ncom) /* for all the committees in the network... */

        if(decsn[ci]!=class[ci]) { /* if the committee goofed up, */
            goofed=TRUE; /* then say so, */
            pats_missed++; /* count misrecognized pattern, */
            sway_tlus(ci); /* and change enough tlu's */
            * so it won't goof up on this pattern next time ! */
        }

    if(goofed) { /* did we goof? */
        missed++; /* yes, count the boo boo! */
        if(log_level>=2) { /* if detail requested, */
            printf("\n"); /* start a new line */
            show_bits("siloam ",decsn); /* show machine's decision */
            show_bits("really ",class); /* display what really is */
        }
    }
}

/*****
 *
 * TOTCONS -- Total Number Of Connects
 *
 *****/

int totcons() { /* count total # of connections */

```

(continued on next page)

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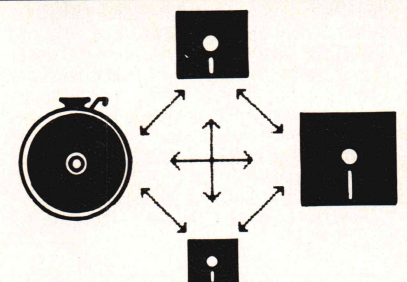
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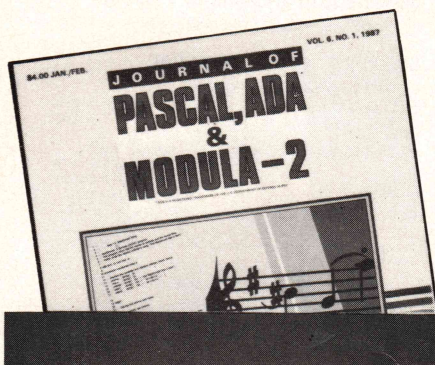
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NEURAL NETWORK

Listing One (Listing continued, text begins on page 16.)

```

committee *n=net; /* neural network pointer */
tlu *c, /* committee pointer */
t; /* tlu pointer */
int i,j,k, /* loop indices */
no=0; /* totalizer accumulator */

forall(i,ncom) { c=n++->wtpt; /* for each committee... */
    forall(j,ntlu) { t=*c++; /* for each tlu in the committee */
        forall(k,dim-1) /* for each element in the tlu */
            if(*t++!=0) no++; /* count it if it is connected */
    }
}

return(no); /* return the count */
}

/*****
 *
 * SILOAM Outside Control Structure
 *
 *****/

void siloam() { /* outside control structure for pattern recognizer */

    long start,stop; /* timer value cells for benchmarking */
    int cons,new,old=0; /* connection counters */

    read_header(); /* read header information in the training file */

    initialize(); /* allocate the committees of TLUs and
                  * initialize the weight points randomly */

    radius_statistics(); /* print starting radius statistics */

    npass=0; /* initialize pass counter */
    start=time(NULL); /* remember start time */

    do { /* start over in training file,
          * we made a mistake... */

        missed=0; /* reset misrecognition counter */

        read_header(); /* rewind training file
                       * and skip over header information... */

        while(read_pattern()) { /* keep reading patterns until we've
                                * done the entire training file and recognized them all */

            recognize(); /* attempt to recognize the pattern */

            train(); /* adjust any weights necessary to get
                     * the correct recognition if we goofed */

            if(goofed&&start_over) break; /* select training strategy */

        } /* end of while loop to read next pattern */

        npass++; /* increment pass counter */
        if(log_level>1) { /* give pass summary report */
            cons=totcons(); /* count the connections */
            new=cons-old; /* compute how many new ones */
            old=cons; /* remember for next time */
            printf("\npass # %d missed %d cons=%d new=%d",
                    npass, missed, cons, new);
        }
    } while(missed); /* end of do loop to train network */

    stop=time(NULL); /* get stop time */

    /***** print end of run summary *****/

    printf("\n");
    printf("\ntraining completed in %ld seconds.\n",stop-start);
    printf("\nnumber of committees: %d",ncom );
    printf("\nnumber of tlus total: %d",ncom*ntlu );
    printf("\nnumber of elements: %d",ncom*ntlu*dim );
    printf("\nnumber of connections: %d",totcons() );
    printf("\n");

    printf("\nnumber of passes thru file: %d",npass);
    printf("\nnumber of patterns in file: %d",pats_so_far );
    printf("\nnumber of mis-recognitions: %d",pats_missed );
    printf("\nnumber of tlu adjustments: %d",tlus_trained);
    printf("\nmaximum element magnitude: %f", (float)maxel);

```



```

printf("\n");

radius_statistics(); /* print ending radius statistics */
}

/*****
*
*   MAIN Program Starts Here
*
*****/

main(paramct,params) /****** main program entry point *****/
int paramct; /* number of parameters on command line */
char *params[]; /* array of pointers to strings for each param */
{
    int i; /* array index variable */

    banner(); /* print program name, version, & release date */

    printf("\nInvoked By:"); /* show how the program */
    for(i=1;i<=paramct;i++) printf(" %s",params[i]); /* was started up! */
    printf("\nelement type is %s",eltype); /* show arithmetic used */
    printf("\n");

    /***** parse the command line *****/

    if(paramct==1) help(); /* if no params, then give help and quit ! */
    patname[0]=0; /* else set pattern filename to null string */

    for (i=1;i<paramct;i++) { /* for each parameter... */

        if('-'==params[i][0]) /* is it an option ? */

            switch(toupper(params[i][1])) { /* yes, which one ? */

                case'O',start_over=TRUE) /* strategy */
                case'L',log_level=atoi(&params[i][2])) /* log detail */
                case'T',ntlu=atoi(&params[i][2])) /* # of TLUs */
                case'R',radius=atof(&params[i][2])) /* init radius */
                case'I',corr_incr=atoi(&params[i][2])) /* fixed incr */
                case'A',absolute=TRUE) /* absolute */
                case'F',fraction=atof(&params[i][2])) /* fractional */

            }

    /***** parse filename *****/

    else if(index(&params[i][0],'.')) /* is '.' in it? */
        move(&params[i][0],patname); /* yes, pattern file */

    else move(".PAT", /* no, default extension is */
        move(&params[i][0],patname)); /* '.pat' for pattern file */

}

/***** check for command line errors *****/

if(patname[0]==0) /* check for missing pattern file name */
    abort(
        "pattern filename not specified!");

if(ntlu==0) /* check for missing number of TLUs */
    abort(
        "number of TLUs per committee not specified!");

/***** open pattern file *****/

if(! (pat=fopen(patname,"r"))) /* if open fails, abort */
    abort(
        "can't open pattern file!");

/***** perform the training and recognition algorithm *****/

/* srand(1); */ /* make random number generator repeatable --
    * ...this may be removed, if desired, after the
    * debug phase is complete! */

siloam(); /* call the outside control structure for the
    * trainable pattern recognizer. */

}

```

End Listing

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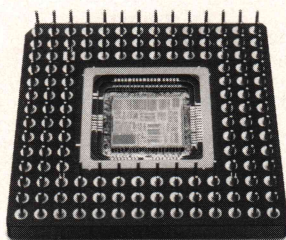


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"How to protect your software by letting people copy it"

By Dick Erett, President of Software Security



Inventor and entrepreneur, Dick Erett, explains his company's view on the protection of intellectual property.

"A crucial point that even sophisticated software development companies and the trade press seem to be missing or ignoring is this:

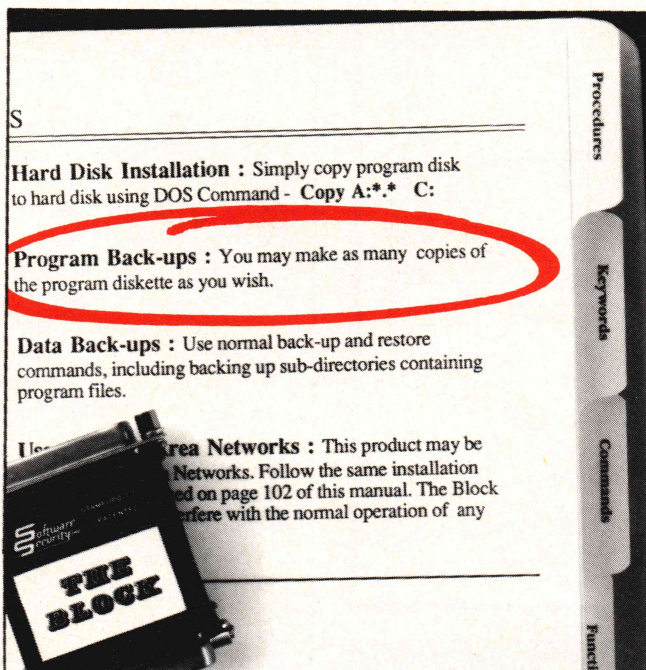
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EXPERT SYSTEMS

Listing One (Text begins on page 42.)

REM Mycin-like expert system for Amiga BASIC
REM by Richard Grigonis

DIM AND.COMPONENT(12),AT.FACTOR.FOR.OR.COMPONENT(12)
DIM OR.COMPONENT(12),TRAIL(30),HUMAN.INPUT\$(4)
DIM MESSAGES(60),WHICH.EQ\$(8),BLANK\$(19)
DIM HYPOTHESIS(20) ' CHANGE THIS NUMBER IF MORE THAN 20 ANIMALS

```
no=0:yes=1
DATA 1,is an albatross
albatross=1
DATA 2,is a penguin
penguin=2
DATA 3,is an ostrich
ostrich=3
DATA 4,is a zebra
zebra=4
DATA 5,is a giraffe
giraffe=5
DATA 6,is a tiger
tiger=6
DATA 7,is a cheetah
cheetah=7
DATA 8,flies well
flies.well=8
DATA 9,swims
swims=9
DATA 10,is black and white
black.and.white=10
DATA 11,cannot fly
cannot.fly=11
DATA 12,has a long neck
long.neck=12
DATA 13,has black stripes
black.stripes=13
DATA 14,has long legs
long.legs=14
DATA 15,has dark spots
dark.spots=15
DATA 16,has a tawny color
tawny.color=16
DATA 17,is a bird
bird=17
DATA 18,is an ungulate
ungulate=18
DATA 19,is a carnivore
carnivore=19
DATA 20,is a mammal
mammal=20
DATA 21,has hair
has.hair=21
DATA 22,gives milk
gives.milk=22
DATA 23,eats meat
eats.meat=23
DATA 24,has pointed teeth and claws and forward pointing eyes
teeth.claws.eyes=24
DATA 25,is a mammal and has hoofs
mammal.and.hoofs=25
DATA 26,is a mammal and chews cud
mammal.and.chews.cud=26
DATA 27,has feathers
feathers=27
DATA 28,flies and lays eggs
flies.and.lays.eggs=28
DATA 29,lays eggs
lays.eggs=29
DATA 30,flies
flies=30
DATA 31,chews cud
chews.cud=31
DATA 32,has hoofs
hoofs=32
DATA 33,has forward pointing eyes
front.eyes=33
DATA 34,has claws
claws=34
DATA 35,has pointed teeth
pointed.teeth=35
DATA -1,END OF DATA
```

REM TOP-LEVEL HYPOTHESES (ROOTS) OF AND/OR TREE:

```
HYPOTHESIS(1)=albatross
HYPOTHESIS(2)=penguin
HYPOTHESIS(3)=ostrich
HYPOTHESIS(4)=zebra
HYPOTHESIS(5)=giraffe
HYPOTHESIS(6)=tiger
HYPOTHESIS(7)=cheetah
number.of.hypotheses=7
```

REM DETERMINE TOTAL NUMBER OF FACTS:

```
number.of.facts=0
WHILE fact <> -1
  READ fact,MESSAGES$
  number.of.facts=number.of.facts+1
WEND
number.of.facts=number.of.facts-1
DIM BEEN.EXAMINED.BEFORE(number.of.facts),OUTPUT.CF
(number.of.facts)
```

Start:

```
FOR A=0 TO UBOUND(OUTPUT.CF)
  OUTPUT.CF(A)=0:BEEN.EXAMINED.BEFORE(A)=0
NEXT A
PRINT "I'm a backward-chaining expert system."
PRINT "Please think of one of the";number.of.hypotheses
PRINT "animals listed below. I will ask you"
PRINT "questions about the animal and compute"
```



```

PRINT "the certainty of it being one"
PRINT "of the following";number.of.hypotheses;"animals:";PRINT
FOR fact=1 TO number.of.hypotheses
  which.fact=HYPOTHESIS(fact)
  GOSUB Find.message:PRINT "ANIMAL ";MESSAGE$
NEXT fact
PRINT

10030 PRINT "DO YOU WANT: "
PRINT "AN EXHAUSTIVE SEARCH (1) OR,"
PRINT "STOP-ON-SUCCESS (2)? ";PRINT
PRINT "Press the NUMBER of YOUR SELECTION"
PRINT "and then press the RETURN KEY."
halt.on.success=0:INPUT halt.on.success
IF 0>halt.on.success OR halt.on.success>2
  THEN PRINT "TRY AGAIN!";GOTO 10030

10050 REM PROVE HYPOTHESES
GOSUB Prove.albatross
IF halt.on.success=2 AND OUTPUT.CF(albatross)=1 THEN 10165
GOSUB Prove.penguin
IF halt.on.success=2 AND OUTPUT.CF(penguin)=1 THEN 10165
GOSUB Prove.ostrich
IF halt.on.success=2 AND OUTPUT.CF(ostrich)=1 THEN 10165
GOSUB Prove.zebra
IF halt.on.success=2 AND OUTPUT.CF(zebra)=1 THEN 10165
GOSUB Prove.giraffe
IF halt.on.success=2 AND OUTPUT.CF(giraffe)=1 THEN 10165
GOSUB Prove.tiger
IF halt.on.success=2 AND OUTPUT.CF(tiger)=1 THEN 10165
GOSUB Prove.cheetah
IF halt.on.success=2 AND OUTPUT.CF(cheetah)=1 THEN 10165

10165 REM DISPLAY RESULTS
CLS
PRINT "HERE ARE THE COMPUTED CERTAINTY FACTORS:"
PRINT "(Correct animal has highest positive CF#)":PRINT
FOR fact=1 TO number.of.hypotheses
  which.fact=HYPOTHESIS(fact)
  GOSUB Find.message
  BLANK$=SPACE$(19)
  MESSAGE$=MESSAGE$+MID$(BLANK$,1,LEN(BLANK$)-LEN(MESSAGE$))
  PRINT "ANIMAL ";MESSAGE$;" CF=";OUTPUT.CF(which.fact)
NEXT fact
PRINT:PRINT "TO GO AGAIN, press the RETURN button."
INPUT HUMAN.INPUT$:PRINT
GOTO Start

REM SUBROUTINES TO COMPUTE CF'S (IN ALPHABETICAL ORDER)
Compute.and.clause.cf:
  GOSUB Find.lowest.cf.branch
  GOSUB Multiply.lowest.cf.by.at.factor
  GOSUB Trim.to.zero
  OUTPUT.CF(TRAIL(depth))-new.cf
RETURN

Compute.or.clause.cf:
  GOSUB Multiply.component.cfs.by.at.factors
  GOSUB Test.for.a.positive.number
  GOSUB Run.or.equation
  GOSUB Trim.to.zero
  OUTPUT.CF(TRAIL(depth))-new.cf
RETURN

Dec.stack:
  depth=depth-1:RETURN

Deduce:
  which.fact=TRAIL(depth):GOSUB Find.message
  PRINT:PRINT "The fact that the animal "
  PRINT MESSAGE$;" (FACT # ";fact.number;" )"
  PRINT "Now has a Certainty Factor of: ";OUTPUT.CF(TRAIL(depth))
  PRINT:GOSUB Dec.stack:GOSUB Delay
RETURN

Delay:
  FOR D=1 TO 10000:NEXT D:RETURN

Explain.why:
  which.fact=TRAIL(1):GOSUB Find.message:CLS
  PRINT "I AM INVESTIGATING THE HYPOTHESIS"
  PRINT "THAT THE ANIMAL..."
  PRINT MESSAGE$;" (FACT # ";fact.number;" )":PRINT
  IF depth=1 THEN
    PRINT "...BY FIRST ASKING YOU.":PRINT
    PRINT "If you are not sure (-8 < CF < 8)"
    PRINT "then I will investigate this hypothesis further."
  ELSE
    FOR A=2 TO depth
      which.fact=TRAIL(A)
      GOSUB Find.message:PRINT "...BY PROVING THAT THE ANIMAL..."
      PRINT MESSAGE$;" (FACT # ";fact.number;" )":PRINT
    NEXT A
    PRINT "...BY ASKING YOU."
  END IF
  PRINT:INPUT "PRESS RETURN KEY TO CONTINUE",HUMAN.INPUT$
RETURN

Find.lowest.cf.branch:
  lowest.number=OUTPUT.CF(AND.COMPONENT(1))
  FOR branch=1 TO number.of.and.clause.components
    number.to.test=OUTPUT.CF(AND.COMPONENT(branch))
    IF lowest.number>number.to.test
      THEN lowest.number=number.to.test
  NEXT branch
RETURN

Find.message:
  RESTORE
  FOR C=1 TO which.fact

```

(continued on next page)

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EXPERT SYSTEMS

Listing One

(Listing continued, text begins on page 42.)

```

READ fact.number, MESSAGE$
NEXT C
RETURN

Inc.stack:
depth=depth+1:TRAIL(depth)=current.fact
RETURN

Multiply.component.cfs.by.at.factors:
FOR branch=1 TO number.of.or.clause.components
new.cf=OUTPUT.CF(OR.COMPONENT(branch))
*AT.FACTOR.FOR.OR.COMPONENT(branch)
GOSUB Trim.to.zero
OUTPUT.CF(OR.COMPONENT(branch))=new.cf
NEXT branch
RETURN

Multiply.lowest.cf.by.at.factor:
new.cf=lowest.number*at.factor.for.and.clause
RETURN

Negative.or.equation:
new.cf=1
FOR branch=1 TO number.of.or.clause.components
new.cf=new.cf*(1+OUTPUT.CF(OR.COMPONENT(branch)))
NEXT branch
new.cf=-1+new.cf
RETURN

Positive.or.equation:
new.cf=1
FOR branch=1 TO number.of.or.clause.components
new.cf=new.cf*(1-OUTPUT.CF(OR.COMPONENT(branch)))
NEXT branch
new.cf=1-new.cf
RETURN

Run.or.equation:
IF WHICH.EQ$="POSITIVE" THEN
GOSUB Positive.or.equation
ELSE
GOSUB Negative.or.equation
END IF
RETURN

Test.fact.for.human.input:
leave=no:GOSUB Inc.stack
IF BEEN.EXAMINED.BEFORE(current.fact)=yes THEN leave=yes:GOSUB
Dec.stack:RETURN
BEEN.EXAMINED.BEFORE(current.fact)=yes
4156 which.fact=current.fact
GOSUB Find.message
4160 CLS:PRINT"(FACT # ";fact.number;")":PRINT
PRINT "ON A SCALE OF -10 TO 10 WHERE,"
PRINT " 10-absolutely certain it's true"
PRINT " 8-almost certain"
PRINT " 6-probably"
PRINT " 3-slight evidence"
PRINT " 0-unknown"
PRINT " -6-probably not"
PRINT " -8-almost certainly not"
PRINT " -10-definitely not"
PRINT:PRINT"TO WHAT DEGREE DO YOU BELIEVE THAT"
PRINT "The animal ";MESSAGE$;"?":PRINT
PRINT "TYPE NUMBER AND PRESS RETURN KEY,"
PRINT "OR TYPE 'why?' AND PRESS RETURN KEY"
INPUT HUMAN.INPUT$
HUMAN.INPUT$=UCASE$(HUMAN.INPUT$)
IF HUMAN.INPUT$="WHY" OR HUMAN.INPUT$="WHY?"
THEN GOSUB Explain.why:GOTO 4156
I=VAL(HUMAN.INPUT$)
IF -10>I OR I>10 THEN GOTO 4160
I=I/10:OUTPUT.CF(current.fact)=I
IF -.8>I OR I>.8 THEN leave=yes:GOSUB Deduce
RETURN

Test.for.a.positive.number:
WHICH.EQ$="NEGATIVE"
FOR branch=1 TO number.of.or.clause.components
number.to.test=OUTPUT.CF(OR.COMPONENT(branch))
IF number.to.test>0 THEN
WHICH.EQ$="POSITIVE":branch=number.of.or.clause.components
NEXT branch
RETURN

Trim.to.zero:
IF -.2<new.cf AND new.cf<=.2 THEN
new.cf=0
ELSEIF new.cf>=.8 THEN
new.cf=1
ELSEIF new.cf<=-.8 THEN
new.cf=-1
END IF
RETURN

REM ***DEDUCTIVE ROUTINES FOLLOW***
Prove.albatross:
current.fact=albatross:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Prove.bird:GOSUB Prove.flies.well
number.of.and.clause.components=2
AND.COMPONENT(1)=bird:AND.COMPONENT(2)=flies.well
at.factor.for.and.clause=1
GOSUB Compute.and.clause.cf
GOSUB Deduce
RETURN

Prove.penguin:

```

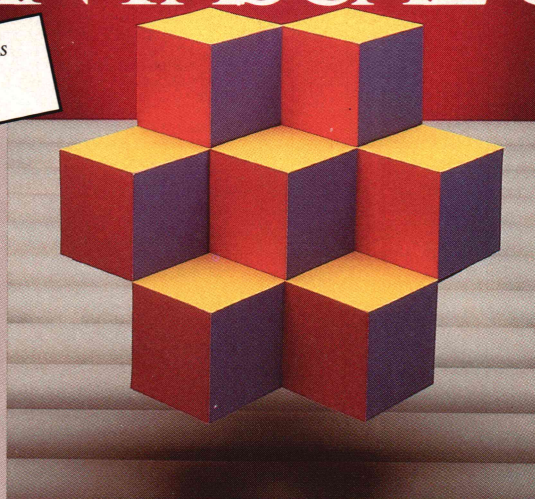
(continued on page 78)

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Listing One

(Listing continued, text begins on page 42.)

```

current.fact=penguin:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Prove.bird:GOSUB Prove.cannot.fly
GOSUB Prove.black.and.white:GOSUB Prove.swims
  number.of.and.clause.components=4
  AND.COMPONENT(1)=bird:AND.COMPONENT(2)=cannot.fly
  AND.COMPONENT(3)=black.and.white:AND.COMPONENT(4)=swims
  at.factor.for.and.clause=.8
  GOSUB Compute.and.clause.cf
GOSUB Deduce
RETURN

Prove.ostrich:
current.fact=ostrich:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Prove.bird:GOSUB Prove.cannot.fly
GOSUB Prove.black.and.white:GOSUB Prove.long.neck
  number.of.and.clause.components=4
  AND.COMPONENT(1)=bird:AND.COMPONENT(2)=cannot.fly
  AND.COMPONENT(3)=black.and.white:AND.COMPONENT(4)=long.neck
  at.factor.for.and.clause=.85
  GOSUB Compute.and.clause.cf
GOSUB Deduce
RETURN

Prove.zebra:
current.fact=zebra:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Prove.ungulate:GOSUB Prove.black.stripes
  number.of.and.clause.components=2
  AND.COMPONENT(1)=ungulate:AND.COMPONENT(2)=black.stripes
  at.factor.for.and.clause=.8
  GOSUB Compute.and.clause.cf
GOSUB Deduce
RETURN

Prove.giraffe:
current.fact=giraffe:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Prove.ungulate:GOSUB Prove.long.neck
GOSUB Prove.long.legs:GOSUB Prove.dark.spots
  number.of.and.clause.components=4
  AND.COMPONENT(1)=ungulate:AND.COMPONENT(2)=long.neck
  AND.COMPONENT(3)=long.legs:AND.COMPONENT(4)=dark.spots
  at.factor.for.and.clause=.85
  GOSUB Compute.and.clause.cf
GOSUB Deduce
RETURN

Prove.tiger:
current.fact=tiger:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN

```

```

GOSUB Prove.mammal:GOSUB Prove.carnivore
GOSUB Prove.black.stripes:GOSUB Prove.tawny.color
  number.of.and.clause.components=4
  AND.COMPONENT(1)=mammal:AND.COMPONENT(2)=carnivore
  AND.COMPONENT(3)=black.stripes:AND.COMPONENT(4)=tawny.color
  at.factor.for.and.clause=.95
  GOSUB Compute.and.clause.cf
GOSUB Deduce
RETURN

Prove.cheetah:
current.fact=cheetah:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Prove.mammal:GOSUB Prove.carnivore
GOSUB Prove.tawny.color:GOSUB Prove.dark.spots
  number.of.and.clause.components=4
  AND.COMPONENT(1)=mammal:AND.COMPONENT(2)=carnivore
  AND.COMPONENT(3)=tawny.color:AND.COMPONENT(4)=dark.spots
  at.factor.for.and.clause=.95
  GOSUB Compute.and.clause.cf
GOSUB Deduce
RETURN

Prove.flies.well:
current.fact=flies.well:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Deduce
RETURN

Prove.swims:
current.fact=swims:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Deduce
RETURN

Prove.black.and.white:
current.fact=black.and.white:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Deduce
RETURN

Prove.cannot.fly:
current.fact=cannot.fly:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Deduce
RETURN

Prove.long.neck:
current.fact=long.neck:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Deduce
RETURN

Prove.black.stripes:
current.fact=black.stripes:GOSUB Test.fact.for.human.input
IF leave=yes THEN RETURN
GOSUB Deduce

```

(continued on page 82)

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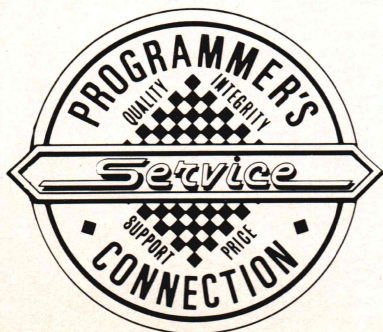
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cobol language

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screenplay for COBOL by Flexus	175	129

debuggers & profilers

386 DEBUG Cross Debugger by Phar Lap	195	129
Advanced Trace-86 by Morgan Computing	175	115
C Code by Computer Innovations	225	CALL
Codisiter Profiler by David Smith	119	85
Codisiter-86 by Visual Age	145	98
DSDB6 by Soft Advances	70	61
DSDB7 by Soft Advances	100	79
MiniProbe by Atron	395	CALL

Periscope I with Board by Periscope	345	289
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Periscope II-X Source only	145	105
The PROFILER with Source Code by DWB	125	89
The WATCHER Profiler by Stony Brook	60	51

dos utilities

Command Plus by ESP Software	New	80
FANSI-CONSOLE by Hersey Micro	75	62
MKS Toolkit with vi Editor by MKS	139	99
Norton Commander by Peter Norton	75	55
Scroll & Recall by Opt-Tech Data	69	59
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entelekon products

C Dynamo	New	250
C Dynamo Screen Painter	New	130
C Function Library	130	109
Dynamo Data Entry	New	130
Power Windows	130	109
Superlerts for C	50	43
Screen Painter & Data Entry	New	180

essential products

C Essentials by Essential Software	100	75
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Essential Comm Library with Debugger	250	189
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Breakout Debugger Any language	125	89
Essential Graphics	250	183

forth language

CFORTH Native Code Compiler by LMI	300	229
Forth/83 Metacompiler Specify Target	750	599
PC/Forth by Laboratory Microsystems	150	109
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fortran language

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FORTLIB by Sutrastof	95	85
FORTLIB Addendum by Impulse Engr	95	85
FORTLIB Addenda by Impulse Engr	165	138
GRAFLIB by Sutrastof	175	159
HALO by Media Cybernetics	300	205
I/O PRO by MEF Environmental	149	129
Microcompilables Combo Package	240	215
Grammatic	135	117
Plotmatic	135	117
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No Limit by MEF Environmental	129	115
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PLOTH by Sutrastof	175	159
PLOTHP by Sutrastof	175	159
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C-Sprite Source Level Debugger	175	129
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with Source Code	250	174
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with Source Code	500	356
dBBC III Plus	New	750
with Source Code	New	1500
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SSP/PC Scientific Subroutine Library	350	269
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microsoft products

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for XENIX	995	609
Microsoft COBOL Tools with Debugger	350	194
for XENIX	450	289
Microsoft FORTRAN w/CodeView	450	269
for XENIX	695	419
Microsoft Learning DOS	50	36
Microsoft LISP Common LISP	250	149
Microsoft MACH 10 w/Mouse & Windows	549	369
Microsoft MACH 10 Board only	399	279
Microsoft Macro Assembler	150	93
Microsoft Mouse Bus Version	175	114
Microsoft Mouse Serial Version	195	124
Microsoft muMath Includes muSIMP	300	179
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other languages

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PolyXREF One language only	129	99	
PVCS Corporate Version Control System	New	395	309
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Interactive EASYFLOW by Haventree	150	125
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Source Print by Aldebaran Labs	75	59
TLIB by Burton Systems Software	100	89
Tree Diagrammer by Aldebaran Labs	55	49

raima products

dbQUERY Single-User Query Utility	195	129
Single-User with Source Code	495	389
Multi-User	495	389
Multi-User with Source Code	990	799
dbVISTA Single-User DBMS	195	129
Single-User with Source Code	495	389
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Multi-User with Source Code	990	799

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Epsilon Emacs-like editor by Luguru	195	147	
KEDIT by Mansfield Software	125	98	
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Turbo EXTENDER by TurboPower Software	85	64
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TurboHALO from IMSI	129	98
TurboPower Utilities by TurboPower	95	78
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Btrieve ISAM File Mgr by SoftCraft	595	454
C-terp by Gimpel, Specify compiler	498	379
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dbVISTA See Raima Section		
dBx with Library Source by Desktop AI	550	489
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Micro Focus Level II Compact COBOL	1000	CALL
Forms-2	400	CALL
Level II ANIMATOR	600	CALL
Microport Products See Microport Section		
Microsoft Products See Microsoft Section		
PANEL Screen Designer by Roundhill	625	535
REAL-TOOLS Binary Version by PCT	149	89
Library Source Version	399	289
Complete Source Version	499	369
RM/COBOL by Ryan-McFarland	1250	CALL
RM/COBOL '85 by Ryan-McFarland	CALL	CALL
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SCO Products See SCO Section		

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programmer's connection

Listing One

(Listing continued, text begins on page 42.)

```

RETURN

Prove.long.legs:
  current.fact=long.legs:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.dark.spots:
  current.fact=dark.spots:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.tawny.color:
  current.fact=tawny.color:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.bird:
  current.fact=bird:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.feathers:GOSUB Prove.flies.and.lays.eggs
  number.of.or.clause.components=2
  OR.COMPONENT(1)=feathers
  AT.FACTOR.FOR.OR.COMPONENT(1)=1
  OR.COMPONENT(2)=flies.and.lays.eggs
  AT.FACTOR.FOR.OR.COMPONENT(2)=.8
  GOSUB Compute.or.clause.cf
  GOSUB Deduce
RETURN

Prove.ungulate:
  current.fact=ungulate:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.mammal.and.hoofs
  GOSUB Prove.mammal.and.chews.cud
  number.of.or.clause.components=2
  OR.COMPONENT(1)=mammal.and.hoofs:
  AT.FACTOR.FOR.OR.COMPONENT(1)=.85
  OR.COMPONENT(2)=mammal.and.chews.cud
  AT.FACTOR.FOR.OR.COMPONENT(2)=.8
  GOSUB Compute.or.clause.cf
  GOSUB Deduce
RETURN

Prove.carnivore:
  current.fact=carnivore:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.eats.meat:GOSUB Prove.teeth.claws.eyes
  number.of.or.clause.components=2
  OR.COMPONENT(1)=eats.meat
  AT.FACTOR.FOR.OR.COMPONENT(1)=.85
  OR.COMPONENT(2)=teeth.claws.eyes
  AT.FACTOR.FOR.OR.COMPONENT(2)=1
  GOSUB Compute.or.clause.cf
  GOSUB Deduce
RETURN

Prove.mammal:
  current.fact=mammal:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.has.hair:GOSUB Prove.gives.milk
  number.of.or.clause.components=2
  OR.COMPONENT(1)=has.hair:AT.FACTOR.FOR.OR.COMPONENT(1)=.85
  OR.COMPONENT(2)=gives.milk:AT.FACTOR.FOR.OR.COMPONENT(2)=.8
  GOSUB Compute.or.clause.cf
  GOSUB Deduce
RETURN

Prove.has.hair:
  current.fact=has.hair:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.gives.milk:
  current.fact=gives.milk:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.eats.meat:
  current.fact=eats.meat:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.teeth.claws.eyes:
  current.fact=teeth.claws.eyes:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.pointed.teeth:GOSUB Prove.claws
  GOSUB Prove.front.eyes
  number.of.and.clause.components=3
  AND.COMPONENT(1)=pointed.teeth:AND.COMPONENT(2)=claws
  AND.COMPONENT(3)=front.eyes
  at.factor.for.and.clause=.85
  GOSUB Compute.and.clause.cf
  GOSUB Deduce
RETURN

Prove.mammal.and.hoofs:
  current.fact=mammal.and.hoofs:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.mammal:GOSUB Prove.hoofs
  number.of.and.clause.components=2
  AND.COMPONENT(1)=mammal:AND.COMPONENT(2)=hoofs

```

```

  at.factor.for.and.clause=.8
  GOSUB Compute.and.clause.cf
  GOSUB Deduce
RETURN

Prove.mammal.and.chews.cud:
  current.fact=mammal.and.chews.cud:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.mammal:GOSUB Prove.chews.cud
  number.of.and.clause.components=2
  AND.COMPONENT(1)=mammal:AND.COMPONENT(2)=chews.cud
  at.factor.for.and.clause=.8
  GOSUB Compute.and.clause.cf
  GOSUB Deduce
RETURN

Prove.feathers:
  current.fact=feathers:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.flies.and.lays.eggs:
  current.fact=flies.and.lays.eggs:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Prove.flies:GOSUB Prove.lays.eggs
  number.of.and.clause.components=2
  AND.COMPONENT(1)=flies:AND.COMPONENT(2)=lays.eggs
  at.factor.for.and.clause=1
  GOSUB Compute.and.clause.cf
  GOSUB Deduce
RETURN

Prove.lays.eggs:
  current.fact=lays.eggs:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.flies:
  current.fact=flies:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.chews.cud:
  current.fact=chews.cud:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.hoofs:
  current.fact=hoofs:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.front.eyes:
  current.fact=front.eyes:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.claws:
  current.fact=claws:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

Prove.pointed.teeth:
  current.fact=pointed.teeth:GOSUB Test.fact.for.human.input
  IF leave=yes THEN RETURN
  GOSUB Deduce
RETURN

```

End Listing

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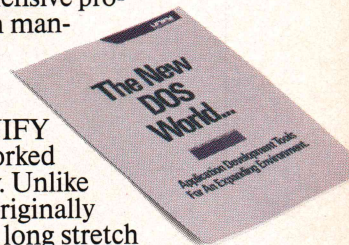


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Listing Nineteen (Text begins on page 130.)

```
#include <stdio.h>
#include <hash.h>
#include "nr.h"

/*-----
 *
 *   NRMAC.C: macro, diversion, & trap support for nr
 *
 *   Copyright (c) 1987, Allen I. Holub.
 *
 *   This module holds routines for manipulating and
 *   accessing macros and strings. In addition the line
 *   trap mechanism is implemented here.
 *
 *-----
 *
 * Macros are kept in a hash table. If they are smaller
 * than MAXMBUF characters, they are stored in memory; else
 * they're stored on the disk. When a macro gets too big it
 * is put into a file called XXXY.mac where XX is the first
 * character in the name represented as two hex digits, YY
 * is the second character.
 *
 * 1) It's incremented after every line is output in nrout.c
 * 2) It's used to spring diversion traps in nrout.c
 * 3) It's used when setting a diversion trap in nrprocs.c
 *
 * it's value is equal to \n\n if no diversion is active.
 * HEIGHT is the height of the most recently completed
 * diversion accessible as \n(dn. It's set equal to VERT
 * when a diversion is closed. It's not used anywhere by nr.
 *
 *-----
 *
 *   MACRO-RELATED DEFINES:
 *
 */

typedef struct _macro_
{
    char mode; /* Open mode: 'r' 'w' 'a' 0-not open */
    FILE *fd; /* Fd of macro on disk or 0 if in memory */
    char *buf; /* Pointer to buffer or 0 if macro on disk */
    char *ptr; /* If buf valid, pointer to the
                /* last valid character. (current char if
                /* writing).
    int vert;
    int width; /* Macro size in lines and macro width in
                /* characters. These fields are only
                /* defined if the macro is a diversion.
}
MACRO;

typedef UCHAR LTRAP[4];

static LTRAP Linetrap[ MAXLTRAP+1 ];
static HASH_TAB *Macros = NULL;

/*-----
 *
 *   DIVERSION-RELATED DEFINES:
 *
 */

typedef struct
{
    FILE *ofile; /* Output file of previous level */
    int isdiv; /* 1 if file is a diversion */
    int divtrap; /* Diversion trap */
    char dtrap_name[2]; /* Invoke when divtrap reached
    int width; /* width of current diversion.
    int vert; /* Vertical place in current div
}
DIV;

#define MAXDIV 8 /* Maximum diversion nesting level */

DIV Dstack[MAXDIV]; /* Diversion environment stack
int Dsp = MAXDIV; /* Diversion stack pointer (index)

/*-----
 *
 *   Function prototypes for external routines not declared
 *   in a .h file
 *
 */

extern void err (char*, ... ); /* nrout.c */
extern int getline (char*,int,int(*)()) ; /* nrinp.c */
extern void process (FILE*,char*,int,char**) ; /* nrinp.c */
extern char *skipspace (char*, int );
extern char *skipto (int, char*, int );
extern char *getenv (char* );

/*-----
 *
 *   Function prototypes for routines in this module
 *
 */

/* MACRO-RELATED (primitives): */

/*global*/ int mgetc (MACRO *, char* );
/*global*/ void mwrite (MACRO *, char* );
/*global*/ void mputc (int, MACRO* );
/*global*/ void munlink (char* );
/*global*/ MACRO *mopen (char*, char* );
/*global*/ void mclose (MACRO* );

/* MACRO-RELATED (high level): */

/*global*/ char *expandstr (char *,char *,int);
/*global*/ int expand_macro (char* );
```

```
/*global*/ int mcreate (char *,char* );
/*global*/ int mappend (char *,char* );
/*global*/ void mac_clean (void);
/*global*/ int screate (char *,char* );
/*global*/ int sappend (char *,char* );
/*global*/ int printm (void);

/* DIVERSION-RELATED */

/*global*/ int dcreate (char* );
/*global*/ int dappend (char* );
/*global*/ int endiv (void);

/* TRAP-RELATED */

/*global*/ int set_linetrap (char *,int );
/*global*/ int movetrap (char *,int ,int );
/*global*/ int pr_traps (void);
/*global*/ int do_divtrap (void);
/*global*/ int do_linetrap (int );
/*global*/ int distance (void);

/* USED LOCALLY */

/*local*/ void delm (char*, MACRO* );
/*local*/ char *fname (char* );
/*local*/ void swrite (MACRO*,char* );
/*local*/ void prnt (char*, MACRO* );
/*local*/ int pushdiv (MACRO* );
/*local*/ MACRO *popdiv (void );
/*local*/ int findtrap (char* );

/*-----
static char *fname( name )
char *name;
{
    /* Create a unique file name for a macro temporary file.
    * The name is volatile (it won't be preserved between
    * fname() calls. If a TMP environment exists, its
    * prefixed to the name.
    */

    static char buf[ 80 ];
    char *env;

    if( !(env = getenv("TMP")) )
        env = "";

    sprintf(buf, "%s%02x%02x.mac", env, name[0] & 0xff,
        name[1] & 0xff);

    return buf;
}

/*-----
MACRO *mopen( m_name, how )
char *m_name;
char *how;
{
    /* Open the macro "m_name" in the specified mode. Mode
    * may be "r" "w" or "a". If the macro doesn't exist it
    * is created. An open for write will delete the contents
    * of the macro if they exist. Only the first two
    * characters of the name mean anything. Return 0 on
    * error or a pointer to the macro on success.
    */

    register int existing ;
    register MACRO *pnode ;
    char *name ;

    if( *m_name == '\0' )
        return( (MACRO *)0 );

    if( !Macros ) /* Create macro table */
        Macros = maketab( 127 ); /* if it doesn't exist.
    name = fname( m_name ); /* Convert macro name to
                             /* associated file name.
    pnode = (MACRO *) findsym(Macros, m_name);
    existing = pnode != NULL;

    if( !pnode )
    {
        pnode = (MACRO*) addsym(Macros, m_name, sizeof(MACRO));
    }
    else if( pnode->mode )
    {
        err("May not access .%2s macro recursively\n", m_name);
        return( (MACRO *)0 );
    }

    switch( pnode->mode = *how )
    {
        case 'a':
            if( existing && pnode->fd )
                pnode->fd = fopen( name, "ab" );

            break;

        case 'w':
            if( existing )
            {
                /* If the macro already exists, truncate it's
                * buffer, or buffer file, to zero
                * length.
                */

                if( pnode->fd )
                    pnode->fd = fopen( name, "w" );
            }
        }
    }
}

(continued on page 86)
```


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Listing Nineteen

(Listing continued, text begins on page 130.)

```

        else if( pnode->buf )
        {
            free( pnode->buf );
            pnode->buf = 0 ;
            pnode->ptr = "" ;
        }
        break;

case 'r':
    if( !existing )
    {
        delsym( Macros, (BUCKET *) pnode );
        return( (MACRO *) 0 );
    }

    /* Position the buffer (or file) pointer to
     * beginning of buffer (or file).
     */

    if( pnode->buf )
        pnode->ptr = pnode->buf ;

    else if( pnode->fd )
    {
        if( !(pnode->fd = fopen( name, "r" ) ) )
        {
            err("Can't open macro file: <%s>\n", name);
            return( (MACRO *) 0 );
        }
    }

    break;

default:
    err("Internal error: bad mopen mode\n");
    return( (MACRO *) 0 );
}

return( pnode );
}

/*-----*/

void mclose( mptr )
MACRO *mptr;
{
    if( mptr )
    {
        if( mptr->fd )
            fclose( mptr->fd ); /* Close the file */

        mptr->mode = 0;
    }
}

/*-----*/

int mgetc( mptr )
MACRO *mptr;
{
    /* Read from a macro opened with a previous mopen call.
     * mgetc is called by getline which is called by
     * process(). It's also called by expandstr() which may
     * be called while expanding a macro. Bunches of
     * recursion, use a big stack. Return EOF at end of macro.
     */

    register int rval;

    if( mptr->buf )
        rval = *mptr->ptr ? (int)(*(mptr->ptr)++) : EOF ;

    else if( mptr->fd )
        rval = ( mptr->fd ) ? getc( mptr->fd ) : EOF ;

    else
        rval = EOF ;

    return rval;
}

/*-----*/

static void swrite( mptr, buf )
MACRO *mptr;
char *buf;
{
    /* Write into a string. buf is a pointer to the
     * string itself and mptr is a pointer to the macro.
     */

    while( *buf )
        mputc(*buf++, mptr);

    mputc( 0, mptr );
}

/*-----*/

void mwrite( mptr, term )
MACRO *mptr;
char *term;
{
    /* Write into a macro. Input is taken from the
     * current input file and put into the macro until
     * a line starting with "term" is encountered. Note

```

```

* that the input is not modified ( escape sequences
* are not expanded, etc.). Terminate on end of file
* or on encountering term at the beginning of a
* line. Mwrite is also used by the .ig command to
* ignore input text. To do this, set mptr to 0.
*/

```

```

char buf[ MAXSTR ], *bp ;
int not_eof ;

while( not_eof = getline(buf,1,ismacro ? mgetc : fgetc) )
{
    if( ! *term ) /* Terminate on .. at bol */
    {
        if( buf[0] == '.' && buf[1] == '.' )
            break;
    }
    else if( *term == '\n' )
    {
        if( !*buf ) /* Terminate on an empty line */
            break;
    }
    else if( buf[0] == '.' && buf[1] == term[0] && buf[2] == term[1] )
        break;

    if( !mptr ) /* For the .ig command. Ignore */
        continue; /* input. */

    for( bp = buf ; *bp ; mputc( *bp++, mptr ) )
        ;

    mputc( '\n', mptr ); /* Getline doesn't buffer LF */
}

if( not_eof )
{
    if( mptr )
        mputc( 0, mptr );
}
else
{
    err("EOF encountered while writing to %s macro\n",
        symname(mptr));
    exit(1);
}
}

/*-----*/

void mputc( c, mptr )
MACRO *mptr;
{
    char *name;

    if( mptr->fd )
    {
        /* Macro is on the disk:
         * Don't write a terminating null to a file. This
         * simplifies our life when we append to a macro
         * in a file.
         */

        if( c )
            putc(c, mptr->fd );
    }
    else if( mptr->buf )
    {
        /* Macro is in memory: Write the character into
         * the buffer. Don't increment when we write a null
         * to make appending easier.
         */

        if( mptr->ptr - mptr->buf < MAXMBUF )
        {
            if( c )
                *(mptr->ptr)++ = c ;
            else
                *mptr->ptr = 0 ;
        }
        else
        {
            /* Macro has grown too large. Create a disk
             * file and write it out to there. Free the
             * memory previously used by the macro.
             */

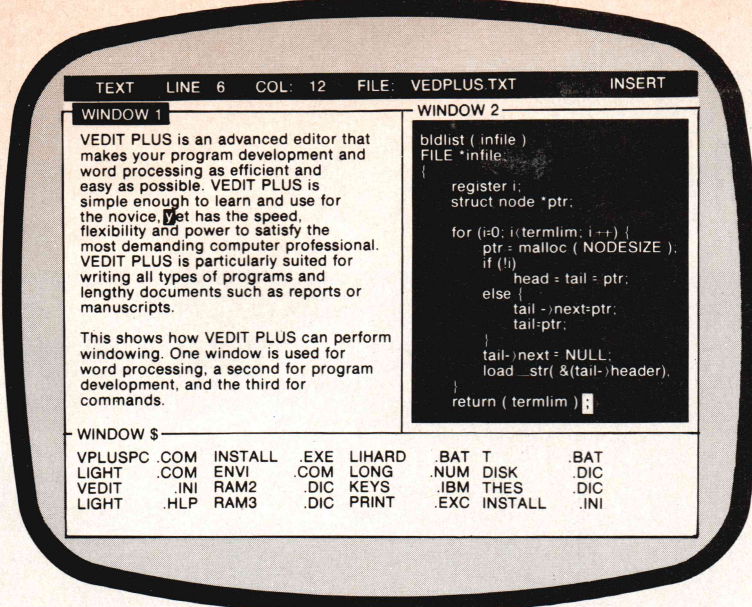
            name = fname( symname(mptr) );

            if( !(mptr->fd = fopen(name, "w")) )
            {
                err("Can't open temporary macro file <%s>\n",
                    name);
            }
            else
            {
                fwrite( mptr->buf, MAXMBUF, 1, mptr->fd );
                free( mptr->buf );
                mptr->buf = mptr->ptr = 0 ;

                if(c)
                    putc(c, mptr->fd);
            }
        }
    }
    else /* New macro, allocate a buffer then write */
    {
        if( mptr->buf = (char *) malloc( MAXMBUF ) )
        {
            mptr->ptr = mptr->buf ;

```

(continued on page 89)



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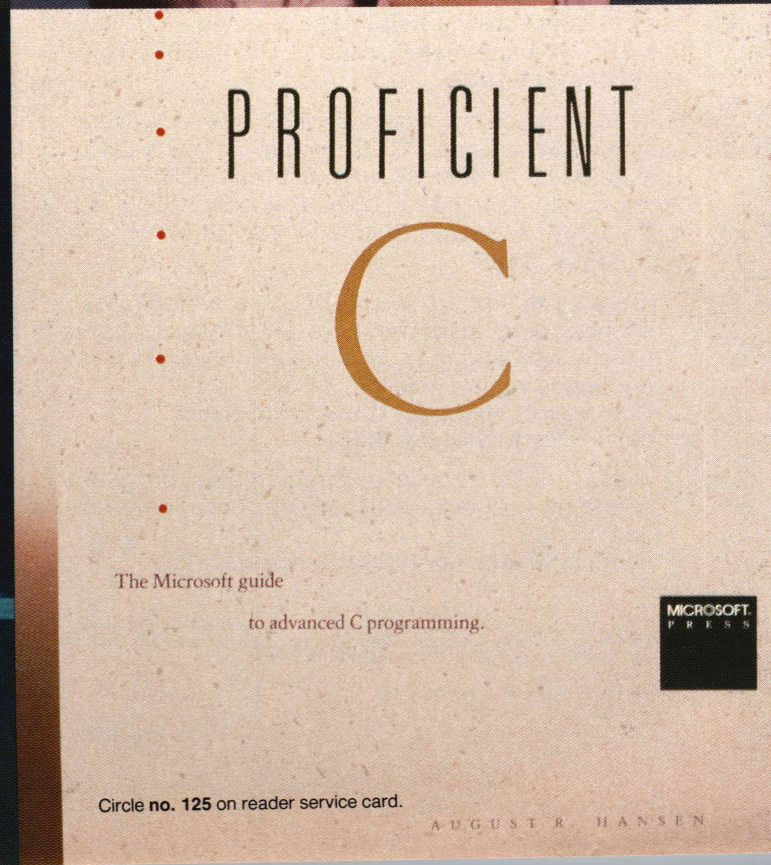
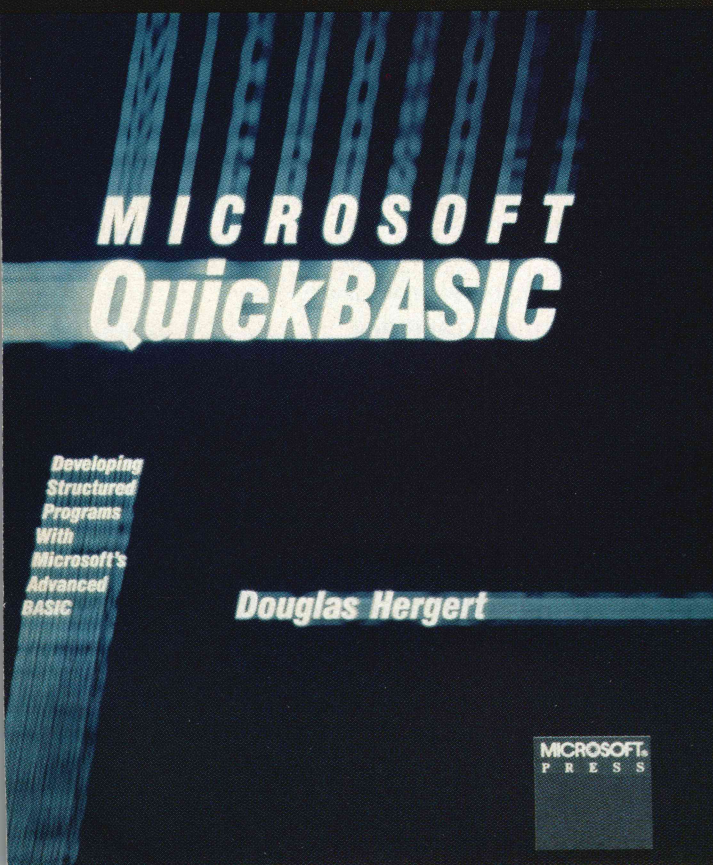
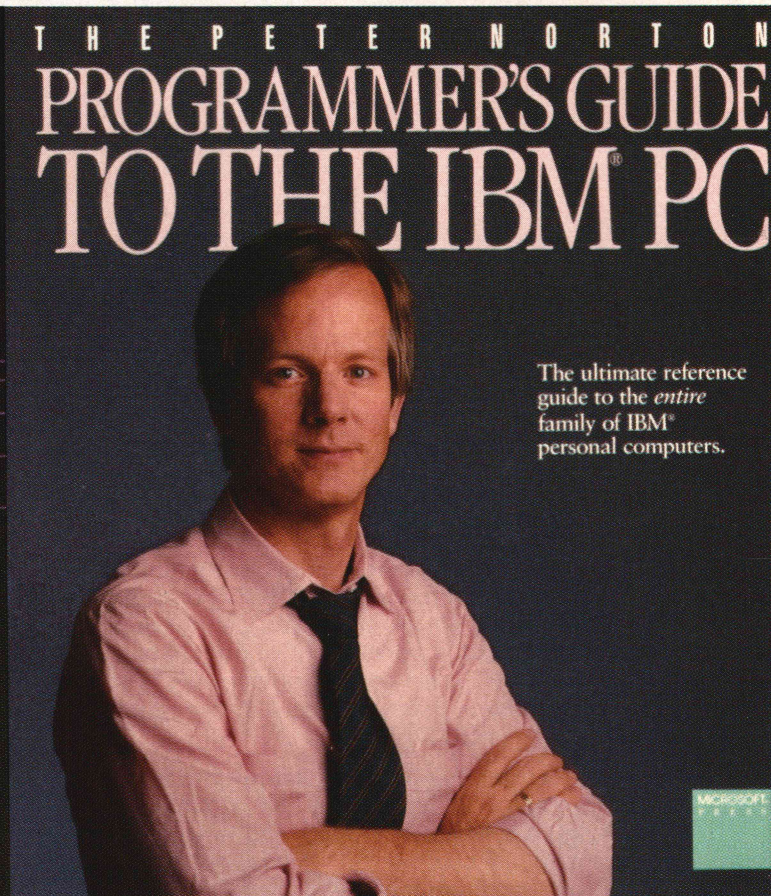
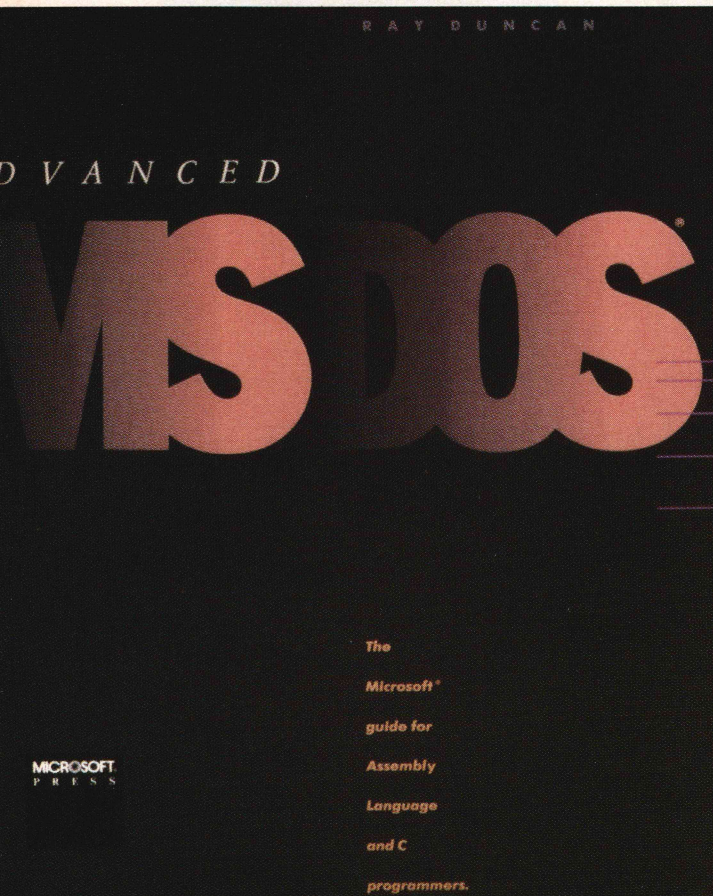
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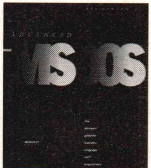
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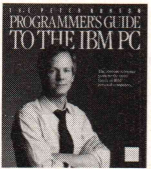
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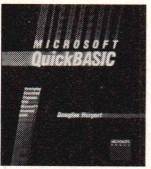
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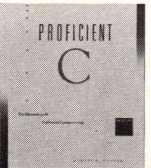
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```

    if( c )
        *(mptr->ptr)++ = c ;
    else
        *mptr->ptr = 0;
}
else
    err("Insufficient memory for macro\n");
}

/*-----*/

void      munlink(m_name)
char      *m_name;
{
    /* Remove macro "m_name" if it exists. Return 0 if
     * the register didn't exist: return 1 if it was
     * removed successfully.
     */

    register MACRO *node;

    if( !(node = (MACRO *) findsym( Macros, m_name )) )
        err("Macro <%2.2s> doesn't exist\n", m_name );
    else
    {
        if( node->mode )
        {
            err("May not remove active macro, aborting\n");
            exit( 1 );
        }

        if( node->buf )
            free( node->buf );

        else if( node->fd )
            unlink( fname( m_name ) );

        delsym( Macros, (BUCKET *) node );
    }
}

/*-----*/

char      *expandstr( name, target, maxstr )
char      *name, *target;
{
    /* Expand str into the target string. Return the updated
     * target pointer, which won't be modified if the string
     * doesn't exist. In this last case print an error message.
     * Expand at most maxstr characters. Note that there's
     * an indirect recursion if the expanded string contains
     * an escape sequence. expandstr() is called from
     * escape().
     */

    register MACRO *mptr;
    register int   c ;
    char          *p ;

    if( mptr = (MACRO *) mopen(name, "r") )
    {
        c = mgetc(mptr) ;

        while( c != EOF && maxstr > 0 )
        {
            if( c != Esc )
            {
                *target++ = c ;
                c = mgetc(mptr) ;
                --maxstr;
            }
            else
            {
                p = target;
                c = escape(p, &target, 0, mgetc, mptr, maxstr);
                maxstr -= (target - p);
            }
        }

        mclose( mptr );
    }

    return target;
}

/*-----*/

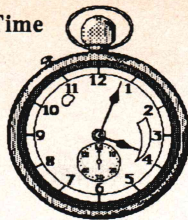
expand_macro( str )
char      *str;
{
    /* Expand the macro. The first word in str is the name.
     * Note that expand is called by process() which calls
     * expand. There can be some nasty recursion
     * going on if macro expansion is nested too far. On the
     * other hand the code needed to expand nested macros
     * is much cleaner. MAXNEST will help this a little.
     *
     * Return 0 if the macro doesn't exist or if the nest
     * level is too high, 1 otherwise.
     *
     * This routine is called recursively in the case of
     * nested macro expansions. Be careful with static
     * variables.
     */

    register int   i, onargs;
    register MACRO *mptr;

```

(continued on next page)

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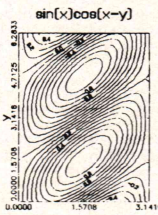
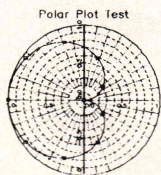
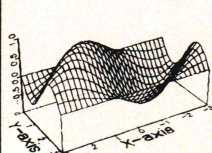
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C CHEST

Listing Nineteen

(Listing continued, text begins on page 130.)

```

char          *macv[MAXARGS], *name ;
static        nestlev = 0 ;
if( nestlev < MAXNEST )
    ++nestlev;
else
{
    err( "Macro nesting too deep, ignoring <%=>\n", str);
    return 0;
}

name = str;
str = skipto( ' ', str, Esc ); /* extract name */
if( *str )
    *str++ = '\0'; /* Skip past name */
str = skipspace(str, Esc); /* terminate name & */
/* skip whitespace */

if( !( mptr = (MACRO *) mopen(name, "r") ) )
    return 0;

/* Create the vector array pointing into the argument
 * array. Null terminate each argument string. Quoted
 * arguments are recognized.
 */

for( i = 0 ; *str && i < MAXARGS ; i++ )
{
    if( *str == '"' )
    {
        macv[i] = ++str ;
        str = skipto( '"', str, Esc );
    }
    else
    {
        macv[i] = str ;
        str = skipto( ' ', str, Esc );
    }

    if( *str )
    {
        *str++ = 0;
        str = skipspace(str, Esc);
    }
}

onargs = NARGS; /* Set # args at current lev */
NARGS = i;

while( i < MAXARGS ) /* Put null in unused args */
    macv[i++] = "" ;

process( (FILE *) mptr, symname(mptr), 1, macv );

NARGS = onargs; /* clean up */
--nestlev;
mclose( mptr );
return 1;
}

/*-----*/

dump_mac( macro, file )
char *macro, *file;
{
    /* Dump the indicated macro out to the indicated file.
    */

    MACRO *mptr;
    FILE *fp;
    register int c;

    if( !(fp = fopen(file, "w")) )
        err("Can't open <%=> for output\n", file );

    else if( mptr = (MACRO *) mopen(macro, "r") )
    {
        while( (c = mgetc(mptr)) != EOF )
            putc(c, fp);

        mclose( mptr );
        fclose( fp );
    }
}

/*-----*/

mcreate( name, term )
char *name, *term;
{
    /* Create a macro. If it already exists, delete it
    * first.
    */

    register MACRO *mptr;

    if( mptr = mopen( name, "w" ) )
    {
        mwrite( mptr, term );
        mclose( mptr );
    }
}

/*-----*/

mappend( name, term )
char *name, *term;
{
    /* Append to an existing macro. Create it if it
    * doesn't exist.
    */

```



```

register MACRO *mptr;

if( mptr = mopen( name, "a" ) )
{
    mwrite( mptr, term );
    mclose( mptr );
}

/*-----*/

screate(name, str)
char *name, *str;
{
    /* Create a string. If it exist, delete it
    */

    register MACRO *mptr;

    if( mptr = mopen( name, "w" ) )
    {
        swrite( mptr, str );
        mclose( mptr );
    }
}

/*-----*/

sappend(name, str)
char *name, *str;
{
    /* Append to an existing string. If it doesn't
    * exist, create it.
    */

    register MACRO *mptr;

    if( mptr = mopen( name, "a" ) )
    {
        swrite( mptr, str );
        mclose( mptr );
    }
}

/*-----*/

static void prnt( m_name, p )
char *m_name;
MACRO *p;
{
    FILE *stream = NULL;
    int len;
    char str[80];

    if( p->buf )
        len = strlen( p->buf );

    else if( p->fd )
    {
        if( !(stream = fopen( fname(m_name), "rb" )))
        {
            err("Can't open %s\n", str );
            return;
        }

        len = filelength( fileno(stream) );
    }

    printf("+----- <%s> (%d chars in %s) -----+\n",
        m_name, len, stream ? "file" : "memory" );

#ifdef DEBUG
    printf("| mode=0x%x<=0x%x, buf=0x%x, ptr=0x%x, fd=0x%x\n",
        p->mode, p->mode, p->buf, p->ptr, p->fd );
    printf("+-----\n");
#endif

    if( !stream )
        fputs( p->buf, stdout );
    else
    {
        while( fgets(str, 80, stream) )
            fputs( str, stdout );

        fclose(stream);
    }

    putchar('\n');
}

/*-----*/

prntm() /* Print out all the macros */
{
    register int lev;

    if( !Macros )
        err("**** There are no macros ****\n");
    else
    {
        ptab( Macros, prnt );
        printf( "\nThe end macro is <%s>\n",
            *Endm ? Endm : "NONEXISTANT" );
    }
}

/*-----*/

static void delm( m_name, p )
char *m_name;
MACRO *p;

```

(continued on next page)

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C CHEST

Listing Nineteen

(Listing continued, text begins on page 130.)

```
(
    /* Delete disk file associated with macro */
    if( p->fd )
        unlink( fname( m_name ) );
}

void mac_clean()
{
    /* Delete all macros that are on the disk */
    if( Macros )
        ptab( Macros, delm );
}

/*-----
* Stuff to handle to diversions. It is too complicated to
* use recursion here, mostly because you can be processing
* a macro while you are diverting output (and have several
* levels of nesting to boot. Modifying process() to handle
* changes in both input and output proved to be too
* difficult. The easy thing to do is maintain a special
* diversion stack on which we keep the various globals we
* want to save when we change diversions. Pushdiv() and
* popdiv() (below) do the stack maintenance.
*/

static int pushdiv( ndptr )
MACRO *ndptr;
{
    register DIV *div;

    if( Dsp <= 0 )
    {
        err("Diversion nesting too deep\n");
        return 0;
    }

    div = &Dstack[--Dsp];

#ifdef DEBUG
    printf("Opening diversion, saving at Dstack[%d]\n",
        Dsp);
#endif

    div->ofile = Ofile ;
    div->isdiv = Isdiv ;
    div->divtrap = Divtrap;
    div->dtrap_name[0] = Dtrap_name[0];
    div->dtrap_name[1] = Dtrap_name[1];
    div->vert = VERT;
    div->width = Divwidth;

    Divwidth = 0;
    Ofile = (FILE *)ndptr; /* Width of current diversion */
    Isdiv = 1; /* output macro pointer */
    Divtrap = -1; /* Ofile points at a macro */
    Dtrap_name[0] = 0; /* No diversion trap set */
    Dtrap_name[1] = 0; /* Diversion trap has no name */

    return 1;
}

/*-----*/

static MACRO *popdiv()
{
    /* Restore the environment active before the most recent
    * push div call. Return a pointer to the diversion macro
    * or 0 if no environment to restore.
    */

    register MACRO *rval;
    register DIV *div;

    if( Dsp >= MAXDIV ) /* No diversion is active */
        return 0;

#ifdef DEBUG
    printf("Closing diversion, popping Dstack[%d]\n", Dsp);
#endif

    div = &Dstack[Dsp++];

    /* Put back the old environment. Note that VERT is
    * initialized to 1 and incremented after every line
    * output to the diversion. This way \n(.d will be 1
    * on line 1 of the diversion. HEIGHT, however, is the
    * height of the most recent diversion (which will be
    * one less than VERT.
    */
    rval = (MACRO *)Ofile;
    Ofile = div->ofile ;
    Isdiv = div->isdiv ;
    Divtrap = div->divtrap ;
    Dtrap_name[0] = div->dtrap_name[0];
    Dtrap_name[1] = div->dtrap_name[1];
    VERT = div->vert;
    Divwidth = div->width;

    return( rval );
}

/*-----*/

dcreate( name )
char *name;
{
    /* Create a diversion from scratch.
    */
}
```


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```

register MACRO *mptr;

if( mptr = mopen( name, "w" ) )
{
    if( !pushdiv(mptr) )
        mclose( mptr );

    VERT    = 1; /* Vertical place in current div */
    Divwidth = 0; /* Width of current diversion */
}
}

/*-----*/

dappend( name )
char *name;
{
    /* Open an existing diversion for appending. The
     * current diversion height and width number registers
     * will be changed to reflect this diversion.
     */

    register MACRO *mptr;

    if( mptr = mopen( name, "a" ) )
    {
        if( !pushdiv(mptr) )
            mclose( mptr );

        VERT    = mptr->vert + 1;
        Divwidth = mptr->width ;
    }
}

/*-----*/

enddiv()
{
    /* Close the most recently opened diversion
     * We must decrement VERT because it's incremented after
     * the final \n of the diversion is processed.
     * If no diversion is active, nothing is done.
     */

    register MACRO *mptr;
    int height, width ;

    height = VERT - 1 ;
    width  = Divwidth ;

    if( mptr = popdiv() )
    {
        mputc( 0, mptr );

        mptr->vert = HEIGHT = height ;
        mptr->width = WIDTH = width ;

        mclose( mptr );
    }
}

/*-----*/
*
* Stuff to handle to traps:
*/

static int findtrap( name )
char *name;
{
    /* Look for the trap associated with the macro
     * "name." Return an index if found, -1 if not.
     */

    register int i;

    for( i = MAXLTRAP+1 ; --i >= 0 ; )
        if( !strcmp(name, Linetrap[i]) )
            return i;

    return -1;
}

/*-----*/

set_linetrap( name, lnum )
char *name;
int lnum;
{
    /* Set a line trap that will execute the macro called
     * "name" when output line number "lnum" is passed. If
     * the name * is missing, clear the trap at the
     * indicated location.
     */

    register UCHAR *lp;

    if( lnum < 0 )
        lnum += PGLEN ;

    lp = (UCHAR *) ( Linetrap + lnum );

    if( lnum < 0 || lnum > MAXLTRAP )
    {
        err("line trap must be in the range 0 - %d\n",
            MAXLTRAP);
    }
    else if( !*name )
    {
        *lp = 0;
    }
    else

```

(continued on next page)

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C CHEST

Listing Nineteen

(Listing continued, text begins on page 130.)

```
{
    *lp++ = *name++ ;
    *lp++ = *name ;
    *lp = 0 ;
}

/*-----*/

movetrp( name, where, isoffset )
char *name;
{
    /* Deal with the .ch command. If "where" is 0
     * delete the trap else move it to the indicated
     * position. If "isoffset" then add "where" to
     * the current position. Note that it is not an
     * error to clear a non-existent trap.
     *
     * The first set_linetrp call deletes the
     * existing trap, the second one reinstalls it
     * at the new location.
     */

    register int i;

    if( (i = findtrap(name)) >= 0 )
    {
        set_linetrp( "", i );

        if( where )
            set_linetrp( name, isoffset? i+where : where );
    }
}

/*-----*/

pr_traps()
{
    /* Print all active traps: */

    register int i, none = 1;

    printf("Line traps:\n");
    for( i = 0; i <= MAXITRAP ; i++ )
    {
        if( Linetrp[i][0] )
        {
            if( none )
            {
                printf("execute: on line:\n");
                none = 0;
            }

            printf(" %2.2s %4d\n", Linetrp[i], i);
        }
    }

    if( none )
        printf( "There are no line traps set.\n");

    if( Divtrap != -1 )
        printf("Diversion trap <%s> set at line %d\n",
            Divtrap_name, Divtrap);

    if( Itrap != -1 )
        printf("Input line trap <%s> set at line %d\n",
            Itrap_name, Itrap);
}

/*-----*/

do_divtrap()
{
    /* Spring the diversion trap */

    if( !expand_macro( Divtrap_name ) )
        err("Can't spring %2.2s from diversion trap\n",
            Divtrap_name );
}

/*-----*/

do_linetrp( lnum )
{
    /* Spring a line trap on line "lnum", if one exists */

    register UCHAR *trap ;

    if( 0 <= lnum && lnum <= MAXITRAP )
    {
        trap = (UCHAR *) ( Linetrp + lnum );

        if( *trap && !expand_macro(trap) )
            err("Can't spring trap for line %d (%2.2s).\n",
                (char *)lnum, trap );
    }
}

/*-----*/

distance()
{
    register char *trap ;
    register int line ;

    /* Compute distance from current line to next trap
     */

    line = OLINE ; /* -- Current output line */
}
```

(continued on page 98)

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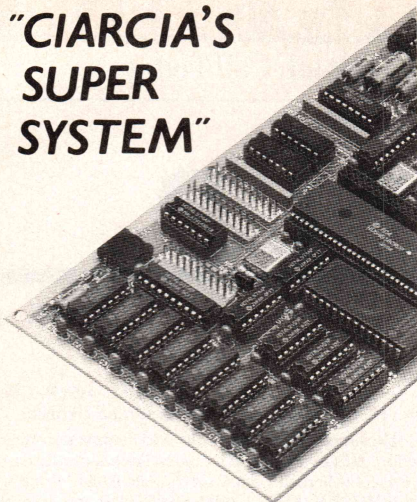
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ECOSOFT

Listing Nineteen

(Listing continued, text begins on page 130.)

```
trap = (UCHAR *) ( Linetrap + OLINE );

while( ++line<=PGLEN && line<=MAXLTRAP && !*trap )
    trap += sizeof(LTRAP);

return line - OLINE ;
```

End Listing Nineteen

Listing Twenty

```
/*-----
 * NRMAMP.C: Routine to map strings of type char to strings
 * of type CTYPE. The only externally accessible
 * subroutine is:
 *
 * void map( dest, src )
 *   UCHAR *src;
 *   CTYPE *dest;
 *
 * Copyright (c) 1987 Allen I. Holub.
 *-----*/
```

```
#include <stdio.h>
#include <ctype.h>
#include "nr.h"
#include "nrmap.h"

void map( dest, src )
UCHAR *src;
CTYPE *dest;
{
    /* Map the input character array over to a CTYPE array
     * in order to get some room for attribute bits (ie.
     * bold, italics, overstruck, etc.). Set the attributes
     * as we process.
     *
     * Only printing characters can have attributes. Motion
     * is transmitted to text() as two bytes, the first
     * indicates the direction and the second is a count.
     * map puts the direction in the low byte and the count
     * in the high byte. If dest == 0 then the various
     * character attributes are set but no other processing
     * is done.
     */

    register unsigned i, c ;
    while( i = *src )
    {
        ++src ;

        if( i==VMOVE || i == HMOVE )
        {
            i = *src++ | MODE_BIT;

            i |= (i == VMOVE) ? VM_BIT : HM_BIT ;

            if( i & 0x80 )
                i |= 0x0f00; /* Sign extend */
        }
        else if( i==CH_FONT )
        {
            Bold = Italics = Over = 0; /* attributes off */

            i = *src++ | (FONT_BIT | MODE_BIT);
        }
        else if( i==CH_ATTRIB )
        {
            if( *src )
            {
                switch( *src++ )
                {
                    case BOLD: Bold = 1; break;
                    case ITALICS: Italics = 1; break;
                    case OVER: Over = 1; break;
                }
            }

            CLRWIDTH( i );
            continue;
        }
        else /* Set the appropriate attribute bits */
        {
            c = i;

            switch(i)
            {
                case LITCHAR: c=i*src++ ; break;
                case SOFT_HYPHEN: c=i*src++ ; HYPHENATE(i); break;
                case ZWIDTH: i=*src++ ; c = -1; break;
                case UP_SPACE: c=i* ' ' ; SETNOPAD(i); break;
            }

            if((Num_under && isalnum(i)) || Cont_ul || Italics)
                SET_UL( i );

            if( !WHITE(i) ) /* Don't boldface or */
            { /* overstrike spaces */
                if( Num_os || Over )
                    SET_OS( i );

                if( Num_bold || Bold )
                    SET_BD( i );
            }

            if( 0 <= c && c <= MAX_CHARS_IN_FONT )
                SETWIDTH( i );
        }
    }
}
```

```
else
    CLRWIDTH( i );
}

if( dest )
    *dest++ = i ;
else
    return;
}

if( Num_under ) --Num_under;
if( Num_bold ) --Num_bold ;
if( Num_os ) --Num_os ;
if( Cont_ul ) --Cont_ul ;

*dest = 0;
}
```

End Listing Twenty

Listing Twenty-one

```
/* NRMSC.C Stuff that didn't fit anywhere else
 *
 * (C) 1987, Allen I. Holub.
 */

#include <stdio.h>
#include <ctype.h>
#include "nr.h"

extern char *skipto();

typedef struct
{
    unsigned adjusting :1; /* adjustment enabled */
    unsigned bold :1; /* boldface active */
    unsigned fill :1; /* filling enabled */
    unsigned italics :1; /* italics active */
    unsigned over :1; /* overstrike active */

    int adjmode; /* adjustment mode (.ad M) */
    int cmd; /* current command character */
    int cont_ul; /* lines to underline (.cu) */
    int curfont; /* Current font (.f) */
    int esc; /* current escape character */
    int indent; /* current indent (.in) */
    int itrap; /* current input line trap */
    char itrap_name[2]; /* name of the above */
    int lspace; /* line spacing (.ls) */
    int nobreak; /* current nobreak character */
    int nm_blanks; /* line numbering stuff (.nm) */
    int nm_on; /* " */
    int nm_mult; /* " */
    char *nm_str; /* " */
    int num_bold; /* # of lines to boldface (.bo) */
    int num_center; /* # of lines to center (.ce) */
    int num_under; /* # of lines to underline (.ul) */
    int num_os; /* # of lines to overstrike (.ul) */
    int offset; /* current page offset (.po) */
    char *rmarg_str; /* margin character */
    char *lmarg_str; /* " */
    int tab; /* tab expansion character */
    int leader; /* leader expansion character */
    int linlen; /* line length (.ll) */
    int tempin; /* temporary indent */
    int title_len; /* length of 3-part title */
    TSTOP tabs; /* previous tab stops */
    int *fillbuf; /* fill buffer contents */
}

ENVIRONMENT;

#define ESTACKSIZE 5

static ENVIRONMENT Env_stack[ESTACKSIZE];
static int Esp = ESTACKSIZE ;

/*-----
 * ENVIRONMENTS (.ev command processing)
 *-----*/

push_env()
{
    ENVIRONMENT *env;
    extern int *saveq();

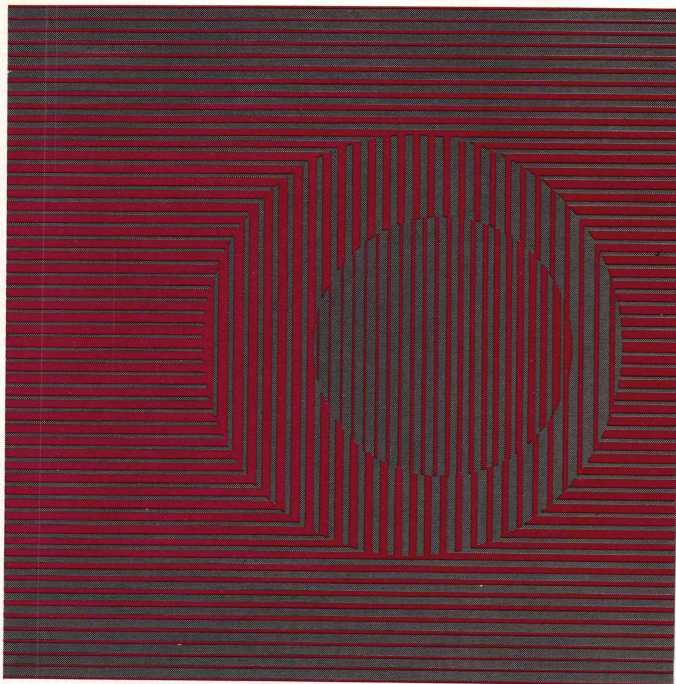
    if( Esp <= 0 )
    {
        err("Environment stack full\n");
        return;
    }

    env = &Env_stack[--Esp];

    env->adjmode = Adjmode;
    env->adjusting = Adjusting;
    env->bold = Bold;
    env->cmd = Cmd_chr;
    env->cont_ul = Cont_ul;
    env->esc = Esc;
    env->fill = FILL;
    env->curfont = CURFONT;
    env->fillbuf = saveq();
    env->indent = INDENT;
    env->italics = Italics;
    env->itrapp = Itrap;
    env->itrapp_name[0] = Itrap_name[0];
    env->itrapp_name[1] = Itrap_name[1];
    env->lspace = LSPACE;
}
```

(continued on page 100)

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Listing Twenty-one

(Listing continued, text begins on page 130.)

```

env->linlen      = LINLEN;
env->nm_on        = Nm_on;
env->nm_blanks    = Nm_blanks;
env->nm_mult       = Nm_mult;
env->nm_str        = Nm_str;
env->nm_bold       = Nm_bold;
env->nm_center     = Nm_center;
env->nm_under      = Nm_under;
env->nm_os         = Nm_os;
env->nobreak       = NobBreak;
env->offset        = OFFSET;
env->over         = Over;
env->rmarg_str     = Rmarg_str;
env->lmarg_str     = Lmarg_str;
env->tab          = Tab;
env->leader       = Leader;
env->tempin       = Tempin;
env->title_len    = Title_len;
memcpy( env->tabs, Tabstop, NUMTABS );
Num_under = 0;
Num_bold = 0;
Num_center = 0;
Num_os = 0;
Bold = 0;
Over = 0;
Italics = 0;
Cont_ul = 0;
Tempin = 0;
}

/*-----*/
pop_env()
{
    ENVIORNMENT *env;

    if( Esp >= ESTACKSIZE )
    {
        err("Environment stack empty\n");
        return;
    }

    D(printf("Restoring from Env_stack[%d]\n", Esp));

    env = &Env_stack[Esp++];

    Adjmode = env->adjmode;
    Adjusting = env->adjusting;
    Bold = env->bold;
    Cmd_chr = env->cmd;
    Cont_ul = env->cont_ul;
    Esc = env->esc;
    FILL = env->fill;
    restorg = ( env->fillbuf );
    INDENT = env->indent;
    Italics = env->italics;
    Itrap = env->itrap;
    Itrap_name[0] = env->itrap_name[0];
    Itrap_name[1] = env->itrap_name[1];
    LINLEN = env->linlen;
    LSPACE = env->lspc;
    Nm_blanks = env->nm_blanks;
    Nm_on = env->nm_on;
    Nm_mult = env->nm_mult;
    Nm_str = env->nm_str;
    Nm_bold = env->nm_bold;
    Nm_center = env->nm_center;
    Nm_under = env->nm_under;
    Nm_os = env->nm_os;
    Nobreak = env->nobreak;
    OFFSET = env->offset;
    Over = env->over;
    Rmarg_str = env->rmarg_str;
    Lmarg_str = env->lmarg_str;
    Tab = env->tab;
    Leader = env->leader;
    Tempin = env->tempin;
    Title_len = env->title_len;
    memcpy( Tabstop, env->tabs, NUMTABS );

    if( CURFONT != env->curfont )
        chgfont( Fonts[CURFONT].name );

    CURFONT = env->curfont;
}

/*-----*/
/* Tabs, Leaders, and Fields */
/*
tabset( s )
char *s;
{
    /* S is a string of comma or space delimited elements
     * of the form:      (+)Nt
     * where N is the position of the tab, t is the type
     * (L/C/R). The optional + means add N to the previous
     * tab stop value.
     */

    int prevtab = 0, tab = 0;

    for( ; *s ; prevtab = tab )
    {
        if( *s == '+' )
        {
            s++;
            tab = prevtab + atoi( &s );
        }
    }
}

```

```

else
    tab = atoi( &s );

if( tab < 1 || tab >= NUMTABS )
{
    err("Tab stop must be in the range 1-4d\n",
        NUMTABS-1);
    return;
}

if( *s == 'R' || *s == 'C' || *s == 'L' )
    Tabstop[tab] = *s++;

else if( *s == ' ' || *s == ',' || !*s )
    Tabstop[tab] = 'L';

while( *s == ' ' || *s == ',' )
    s++;
}

/*-----*/
tabclr()
/* Clear all tabs */
{
    memset( Tabstop, 0, NUMTABS );
}

/*-----*/
tabprint()
/* Print tabs */
{
    register int i;

    for( i = OFFSET; --i >= 0 ; outc(' ') )
        ;

    for( i = 1; i <= LINLEN ; i++ )
        outc( Tabstop[i] ? Tabstop[i] : '.' );

    outc('\r');
    outc('\n');
}

/*-----*/
/* FONT support routines: */
/*
findfont( fname )
int fname;
{
    /* Search for a font in the font table ( Fonts[] ).
     * Return an index into the table or -1 if the
     * entry isn't there.
     */

    register int i;
    register FONT *fp;

    if( fname == 'R' ) /* Roman font is at Font[0] */
        return 0;

    if( isdigit( fname ) )
    {
        if( ( i = fname - '0' ) > NUMFONTS-1 )
            err( "%d: Illegal font number\n", i );

        else if( ! Fonts[i].name )
            err( "Font number %d is undefined\n", i );

        else
            return i;
    }
    else
    {
        fp = &Fonts[NUMFONTS-1];

        for( ; fp > Fonts ; --fp )
            if( fp->name == fname )
                return( fp - Fonts );
    }

    return -1;
}

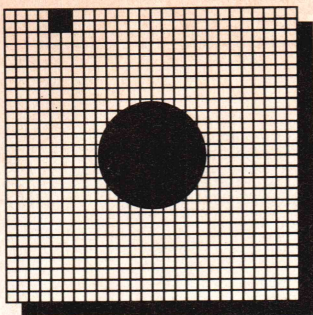
/*-----*/
chgfont( nfont_name )
{
    /* Called from nrount.c to actually change fonts.
     * nfont and prevfont are indexes into the Fonts[]
     * table for the new and previous fonts. The CURFONT
     * number register holds the index for the current font.
     * Fonts[0] is the Roman font.
     */

    int nfont;
    static int prevfont = 0; /* Roman */
    FONT *p;

    if( nfont_name == PREVIOUS )
    {
        nfont = prevfont;
        prevfont = 0;
    }
    else if( ( nfont = findfont(nfont_name) ) < 0 )
    {
        err( "Font <%c> unavailable, using (R)oman\n",
            nfont_name );
        nfont = 0;
    }
}

```

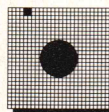
(continued on page 102)



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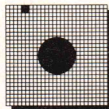
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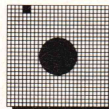
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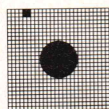
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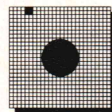
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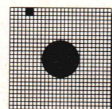
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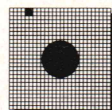
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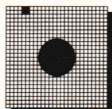
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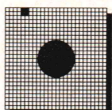
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Circle no. 363 on reader service card.

Listing Twenty-one

(Listing continued, text begins on page 130.)

```

if( CURFONT != nfont )
{
    if( *Fonts[CURFONT].emac )
        expand_macro( Fonts[CURFONT].emac );

    p = &Fonts[nfont] ;

    Right_str = p->right ;
    Left_str = p->left ;
    Hs_amt = p->resolution ;

    if( *(p->smac) )
        expand_macro( p->smac );
}

prevfont = CURFONT;
CURFONT = nfont ;

```

End Listing Twenty-one

Listing Twenty-two

```

/*-----
 * NROUT.C:      Output routines for nr.
 *
 * Copyright (c) 1987 Allen I. Holub. All rights reserved.
 *-----*/

#include <stdio.h>
#include <ctype.h>
#include <stdarg.h>
#include "nr.h"
#include "nrmap.h"
#include "nrtlen.h"

/*-----
 * isword(c)      evaluates to true if c can be in a word. Words
 *                are composed of all characters except padable
 *                space characters.
 *-----*/

#define isword(c) ( ! (WHITE(c) && PADDALE(c)) )

/*-----*/

err( fmt )
char *fmt;
{
    /* Print out an error message. If a macro is being
     * processed, the macro name is given, otherwise the
     * current input file name is given. This routine
     * works like printf() in all other respects.
     */

    va_list args;
    va_start( args, fmt );

    fprintf( stderr, "\007ERROR(%s%s, line %d): ",
             !macro ? "macro " : "",
             !filename ? "filename : " : "stdin", INLINES);

    vfprintf( stderr, fmt, args );
}

/*-----*/

ngaps( line, total_units, total_chars )
CTYPE *line;
int *total_units;
int *total_chars;
{
    /* Returns the number of paddable space characters on
     * the line. Modifies *total_units to hold the number
     * of horizontal units occupied by non-space characters.
     * *total_chars is modified to hold the total number of
     * characters on the line.
     */

    register int utotal = 0;
    register int ngaps = 0;
    CTYPE *p;
    FONT *ftab;

    for(p = line; *p ; ++p )
    {
        if( WHITE(*p) )
        {
            ++ngaps;
        }
        else if ISCHAR( *p )
        {
            utotal += CWIDTH( *p );

            D( printf( "ngaps(): %c ", *p ) );
            D( printf( "- %d units\n", CWIDTH(*p) ) );
        }
    }

    *total_chars = p - line ;
    *total_units = utotal;

    return ngaps;
}

/*-----*/

```

```

radjust( line, col )
CTYPE *line ;
int col ;
{
    /* Do right adjustment. That is spread the words
     * as evenly as possible on the line so that the
     * rightmost character of the rightmost line is at
     * the indicated column (col). This is accomplished
     * by replacing all paddable space characters with
     * motion characters.
     */

    static int left = 0;
    int num_units, num_chars, gaps, need ;
    int space_between_characters;
    int extra_space;

    gaps = ngaps( line, &num_units, &num_chars );

    if( gaps == 0 )
        return;
    need = (col * SPACE_SIZE) - num_units ;
    space_between_characters = need / gaps ;
    extra_space = need % gaps ;

    D( outints( "radjust(), input line:", line ) );
    D( printf( "Total units = %d, ", num_units ) );
    D( printf( "total chars = %d\n", num_chars ) );
    D( printf( "Padding to %d columns", col ) );
    D( printf( "- %d units\n", col * SPACE_SIZE ) );
    D( printf( "%d gaps spread over %d units\n", gaps, need) );
    D( printf( "%d units/gap, ", space_between_characters ) );
    D( printf( "%d extra units\n\n", extra_space) );

    for( gaps > 0 ; line++ )
    {
        if( WHITE(*line) )
        {
            --gaps;
            *line = MOTION( space_between_characters );

            if( left || (gaps <= extra_space) )
            {
                if( --extra_space >= 0 )
                    ++(*line);
            }
        }

        left = !left;
    }
}

/*-----*/

justify( line, mode )
CTYPE *line ;
int mode ;
{
    /* Do simple line adjustment on str (ie. do left,
     * right or center mode adjusting). If the
     * adjustment mode is BOTH then the routine radjust()
     * is called and we don't do anything here.
     */

    int num_units, num_chars, need, gaps ;

    if( !*line || mode == LEFT ) /* Left adjustment */
        return; /* is no adjustment */

    if( mode == BOTH )
        return radjust( line, TLEN );

    gaps = ngaps( line, &num_units, &num_chars );
    need = U_TLEN - (num_units + (gaps * SPACE_SIZE));

    if( need <= 0 )
        return;

    memcpy( line + 1, line, (num_chars + 1) * sizeof(CTYPE));
    *line = MOTION( mode==CENTER ? need/2 : need );
}

/*-----*/

title( instr )
char *instr ;
{
    /* Do a three part title: /str1/str2/str3/
     * The character held in Page_ch is expanded to the
     * current page number. In the absence of an argument
     * do nothing.
     *
     * Titles are done using the normal output function.
     * The delimiters are replaced with normal spaces and
     * normal spaces are replaced with unpaddable spaces.
     * Then outbuf() is called with adjustment mode
     * turned on to print the line. Outbuf() will spread
     * the three parts of the title evenly on the line.
     */

    UCHAR *s;
    int delim, ndelim ;
    static CTYPE dest[ MAXSTR ];
    int i, fmt;
    UCHAR pagenum[60];

    if( !(delim = *instr++) )
        return ;

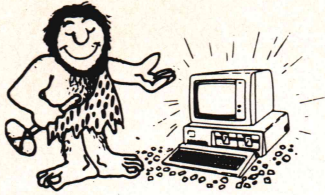
    ndelim = 3;
    for( s = instr; *s ; s++ )

```

(continued on page 104)

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Listing Twenty-two

(Listing continued, text begins on page 130.)

```

{
    if( *s == ' ' )
    {
        *s = UP_SPACE;
    }
    else if( *s == Page_ch )
    {
        deletes( 1, s );

        i = nrtol( "%", &fmt );
        itoa( pagenum, fmt, i );
        s += inserts( pagenum, s, MAXSTR ) - 1;
    }
    else if( *s == delim )
    {
        if( --ndelim > 0 )
            *s = ' ';
        else
        {
            *s = '\\0';
            break;
        }
    }
}

map( dest, instr ); /* map to CTYPE array */
radjust( dest, Title_len ); /* Spread the line */

pad( OFFSET ); /* Output page offset, */
outs( dest ); /* title string, */
outchar( TO_CTYPE('\\n') ); /* and a newline */
}

/*-----*/

outbuf( line, addhyphen )
register CTYPE *line;
{
    /* Output a line of text, adding indent, and page
    * offset. Add a \\n at eol. Do line adjusting or
    * centering as required. If addhyphen is true, a hyphen
    * is added immediately after the line is printed.
    *
    * The line array must be MAXSTR characters long.
    *
    * This routine is called by dofill when filling is on
    * and is called directly by text when it is not. If
    * Nospace is enabled (by a .ns command) then lines
    * consisting of single newline characters will not
    * be printed.
    *
    * If *line is null then we are printing a blank line.
    * In this situation line numbering (.nm) is not done
    * and only one blank line will be printed, regardless
    * of the line spacing (.ls). If there is not left or
    * right margin string defined, no offset is printed.
    */

    register int i;
    char numbuf[32];

    D( outints( "outbuf", line ); )

    if( !*line && Nospace )
        return;

    Nospace = 0; /* Re-enable spacing on a non-blank */
                /* line. */
                /* Then output the page offset and */
                /* the left margin string */

    if( !Isdiv && (*line || *Lmarg_str || *Rmarg_str) )
        pad( OFFSET );

    if( *Lmarg_str )
        outchs( Lmarg_str );

    if( Nm_on && (Nm_blanks || *line) )
    {
        /* Number the line if necessary
        */
        if( LINE % Nm_mult )
            pad( Strlen(Nm_str) + 3 );
        else
        {
            sprintf(numbuf, "%3d%s", LINE, Nm_str );
            outchs( numbuf );
        }
        LINE++;
    }

    if( *line ) /* followed by the line if there */
    {
        pad( INDENT + Tempin );

        /* Now, either center or adjust the line as
        * required. Note: Num_center (set by the .ce
        * command) is different from a centering
        * adjustment mode (ie. the former applies to
        * input lines, the latter to output lines.
        * Centering and adjusting are mutually exclusive.
        */

        if( addhyphen )
        {
            /* This kludge tricks justify() into
            * thinking that the line is shorter than
            * it really is when we add a hyphen.
            */
            Tempin++;
        }

        if( Num_center )
        {
            justify( line, CENTER );
            --Num_center;
        }
        else if( Adjusting )
            justify( line, Adjmode );

        if( addhyphen )
            --Tempin;
    }

    pad(i)
    register int i;
    {
        /* Print i spaces using outchar()
        */

        while( --i >= 0 )
            outchar( TO_CTYPE(' ') );
    }

    /*-----*/

    outc( c )
    int c;
    {
        /* Lowest level output function. Handles control
        * character suppression. "Ispage" tests to see if a
        * page is in the list specified with a -o command line
        * switch. Note that direct calls to outc don't update
        * any global variables. outchar() is the normal output
        * function and should be used except in wierd
        * situations (ie. the .ou command). Note that \\n is not
        * translated into \\r\\n by outc (it is so translated by
        * outchar).
        *
        * Note that outc() processes normal char's, not CTYPE's.
        *
        * A minor problem here is diversions. We are writing
        * in untranslated mode so that control sequences can
        * get to the printer unmolested. With diversions though,
        * we need to translate character by hand (strip off \\r)
        * so that when they are read back (via mgetc) they
        * won't be re-translated on output.
        */

        c &= 0xff;

        if( Isdiv ) /* If we're processing a */
        { /* diversion, put the text */
            if( c != '\\r' ) /* there. */
                mputc( c, Ofile );
        }
        else if( Ispage( PAGE ) )
        {
            /* If this is a printing page as per the -o flag
            * print the character
            */

            if( No_cntl && (c < ' ' || c > 0x7f) )
            {
                printf( "<%02x>", c );
                if( c == '\\n' )
                    printf( "\\n" );
            }
            else
            {
                /* It's virtually impossible to get untranslated
                * standard output out of the Microsoft compiler.
                * so do it here with a direct DOS call.
                */

                bdos( 2, c & 0xff, 0 ); /* putc( c, stdout ) */
            }
        }
    }

    /*-----*/

    outchar( big_c )
    CTYPE big_c;
    {
        /* Medium level character output function. Translates
        * attributes into strings (ie. for bold chars etc.).
        * Updates the line and page numbers when necessary.
        * Springs traps as required.
        * Handles the various motion escape sequences \\u \\d etc.
        * Returns the width on the output line of c. This will
        * be 0 if c is a motion character, a change font, a
        * newline, etc. It will be 1 otherwise.
        *
        * Note that outchar() is passed CTYPE's, not normal
        * characters.
        */

        register unsigned int rval, c;
        static int lastch = 0;
        int width;

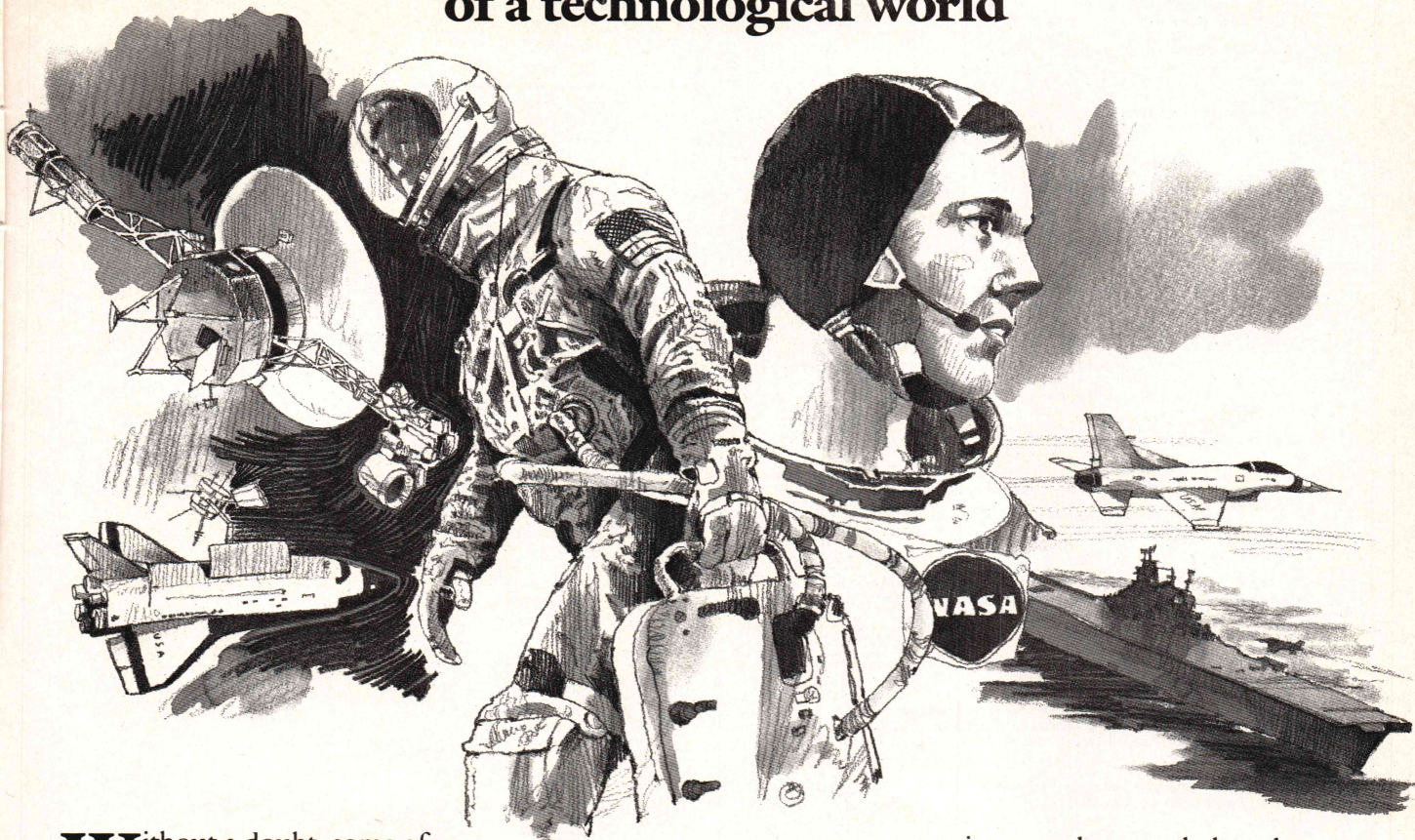
        rval = 0;

        if( ISMOTION(big_c) )
        {
            do_ul ( (CTYPE)0 ); /* All attributes off first */
            do_bold( (CTYPE)0 );
        }
    }
}

```

(continued on page 106)

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Listing Twenty-two

(Listing continued, text begins on page 120.)

```

do over( (CTYPE)0 );
motion( MVAL(big_c), big_c );
else if( ISFONT(big_c) )
{
    do_ul ( (CTYPE)0 );
    do_bold( (CTYPE)0 );
    do_over( (CTYPE)0 );
    chfont( FVAL(big_c) ); /* then change fonts */
}
else
{
    do_ul (big_c); /* ... or print a character: */
    TEXTLEN = outs( line ); /* Underline character if reqd. */
    /* Finally output the line */
    if( addhyphen )
    {
        TEXTLEN++;
        outchar( TO_CTYPE('-') );
    }

    /* Print the right margin character if needed. The
    * first call to pad() (in the if) prints the left
    * margin padding only if this is a blank line (normally
    * we don't want to print any padding on blank lines).
    * The call to pad() gets us to the right margin.
    */

    if( *Rmarg_str )
    {
        if( !*line )
            pad( INDENT + Tempin );

        pad( TLEN - TEXTLEN );
        outchs(Rmarg_str);
    }

    /* Reset Temporary indent. We couldn't do it earlier
    * because it's used in the TLEN macro. We don't want
    * to reset it if the line is blank though.
    */

    if( *line )
        Tempin = 0;

    /* Output at least 1 but as many newlines as are
    * required by the .ls N command. Only one line is
    * output if we are doing a blank line.
    */

    for( i = (*line ? LSPACE : 1); --i >= 0; )
        outchar( TO_CTYPE('\n') );
}

/*-----*/
outs( line )
CTYPE *line;
{
    /* Output an integer string using outchar().
    * Returns amount of space occupied on the output
    * line by p. This will not include motion, font
    * changes, etc.
    */

    register rval = 0;

    D( outints( "outs", line); )

    while( *line )
        rval += outchar( *line++ );

    return rval;
}

#ifdef DEBUG /*-----*/
outints( str, line )
char *str;
CTYPE *line;
{
    /* Output a CTYPE string using putchar, putting
    * "str" in front of it.
    */

    printf("%s <", str );

    for( ; *line ; putchar( *line++ & 0xff ) )
        ;

    printf(">\n");
}
#endif /*-----*/

outchs( str )
char *str;
{
    /* Output a character string using outchar() */

    while( *str )
        outchar( TO_CTYPE( *str++ ) );
}

/*-----*/
ots( str )
char *str;
{
    /* Output a character string using outc. Note that
    * \n will not be translated into \r\n and no global
    * vars will be updated.
    */

    while( *str )
        outc( *str++ );
}

/*-----*/
do_bold( big_c ); /* Boldface character if reqd. */
do_over( big_c ); /* Overstrike character if reqd. */
c = CHAR(big_c); /* Translate to normal char */

if( c == '\n' )
{
    nextline( lastch == '\n' );
}
else
{
    width = CWIDTH( big_c );

    if( width > 1 ) /* In a proportional font */
        motion( width/2, (CTYPE)(MODE_BIT|HM_BIT));

    outc( c ); /* Print char and advance */
    /* 1 HMI unit */

    if( width > 1 )
        motion( (width/2) - 1,
            (CTYPE)(MODE_BIT|HM_BIT));

    if( !HASWIDTH(big_c) )
        motion( -Fonts(CURFONT).widths[c],
            (CTYPE)(MODE_BIT | HM_BIT));

    rval = 1;
}

lastch = c;
}

return rval;
}

/*-----*/
motion( count, how )
int count;
CTYPE how;
{
    /* Take care of motion. \u \d \v etc. */

    register int negative = 0;

    if( count < 0 )
    {
        negative = 1;
        count = -count;
    }

    while( --count >= 0 )
    {
        if( HORIZONTAL(how) )
            ots( negative ? Left_str : Right_str );
        else
            ots( negative ? Up_str : Dn_str );
    }
}

/*-----*/
nextline( harder )
{
    /* - Adjust the line and page numbers or diversion
    * height as appropriate.
    * - Spring a line trap if one is present. A line
    * trap is expanded when a "line of text is output
    * whose vertical size reaches or sweeps past the
    * trap position." In other words, a line trap at
    * line 10 will be triggered immediately after line
    * 10 is printed. Trap 0 is used to spring a trap
    * at the top of the page; it is done in outchar()
    * before the first character on a page is printed
    * (we can't do it at the end of the current page
    * because it wouldn't be sprung on the first page).
    * - Adjust various number registers as appropriate.
    * - Process the -s command line switch if one was
    * given.
    * - Translate \n into \r\n or do Wordstar mode if
    * necessary.
    */

    extern int Stop; /* Declared in nr.c */

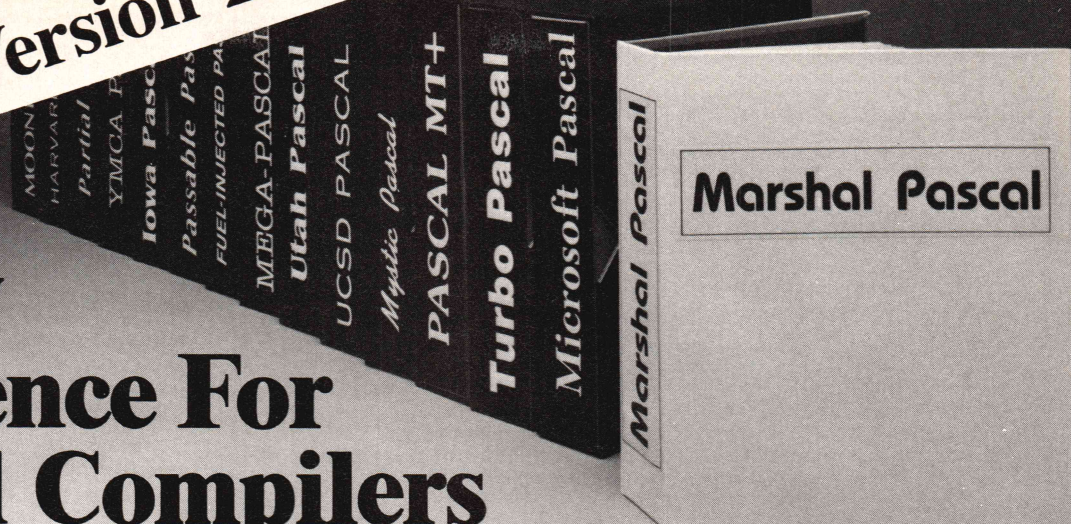
    if( !Wordstar ) /* Not in wordstar mode */
    {
        outc( '\r' );
        outc( '\n' );
    }
    else if( harder ) /* In wordstar mode: */
    {
        outc( '\r' ); /* Saw two successive */
        outc( '\n' ); /* newlines in */
        outc( '\r' ); /* outchar(). */
        outc( '\n' );
    }
    else if( Wordstar == 1 ) /* Use Wordstar soft */
    { /* carriage return for */

```

(continued on page 108)

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Listing Twenty-two

(Listing continued, text begins on page 130.)

```

        outc( 0x8d );      /* newlines          */
        outc( '\n' );

    }
    else
        outc( ' ' );      /* Replace newline with /*
                           /* a space character */

    if( Isdiv )           /* Adjust diversion height and width */
    {                     /* and spring trap if appropriate */
        if( Divwidth < TEXTLEN )
            Divwidth = TEXTLEN ;

        if( Divtrap == VERT )
            do_divtrap();

        ++VERT ;         /* increment diversion height */
    }
    else
    {
        /* Spring any line traps for the current line and
        * then adjust the distance to the next trap. Note
        * that the line number has to be incremented as
        * part of the do_linetrap() call or else the trap
        * for the current line will be sprung recursively.
        */

        do_linetrap( OLINE++ );

        TOTRAP = distance();

        if( OLINE > PGLEN )
        {
            if( Stop && !(PAGE % Stop) )
            {
                /* Process the -s command line switch */

                fprintf(stderr, "\nHit any key to continue.");
                getchar();
            }

            OLINE = 1 ;      /* Adjust line and page # */
            ++PAGE;

            do_linetrap(0);  /* Spring top of page trap */

            TOTRAP = distance();
        }
    }

    /*-----*/

go_up( amt )
{
    /* Called from sp(), in nrprocs.c, to handle negative
    * spacing. Amt is a negative number.
    */

    if( Isdiv )
        VERT = max( VERT + amt, 0 );
    else
    {
        OLINE = max( OLINE + amt, 1 );
        TOTRAP = distance();
    }

    motion( Vs_amt * amt, (CTYPE) ( MODE_BIT | VM_BIT ));

    /*-----*/

do_ul( c )
CTYPE c;
{
    /* Take care of underlining c but don't actually print
    * c. If Ul_on is defined toggle underline mode at the
    * printer at the appropriate times. If Ul_on is not
    * defined then just print a "_\b".
    */

    static int amunder = 0 ;

    if( Plain )
        return;

    if( IS_UL(c) )
    {
        if( *Ul_on )
        {
            if( !amunder )
            {
                amunder = 1;    /* Turn on underlining */
                ots( Ul_on );
            }
        }
        else
            ots( "_\b" );
    }
    else
    {
        if( *Ul_off && amunder )
            ots( Ul_off );

        amunder = 0;          /* Turn off underlining */
    }
}

/*-----*/

```

```

do_bold(c)
CTYPE c;
{
    /* Same as above but do boldface instead of underline
    */

    static int ambold = 0 ;

    if( Plain )
        return;

    if( IS_BD(c) )
    {
        if( *Bd_on )
        {
            if( !ambold )
            {
                ambold = 1;
                ots( Bd_on );
            }
        }
        else
        {
            outc( (int) c );
            outc( '\b' );
        }
    }
    else
    {
        if( *Bd_off && ambold )
            ots( Bd_off );

        ambold = 0;          /* Turn off boldface */
    }
}

/*-----*/

do_over(c)
CTYPE c;
{
    /* Same as above but do overstrike.
    */

    static int am_os = 0 ;

    if( Plain )
        return;

    if( IS_OS(c) )
    {
        if( *Os_on )
        {
            if( !am_os )
            {
                am_os = 1;
                ots( Os_on );
            }
        }
        else
            ots( "-\b" );
    }
    else
    {
        if( *Os_off && am_os )
            ots( Os_off );

        am_os = 0;          /* Turn off overstrike */
    }
}

}

```

End Listing Twenty-two

Listing Twenty-three

```

#include <stdio.h>
#include "nr.h"

/*-----*/
* NRTAB.C -- Tab-processing stuff for NR
*
* (C) 1987, Allen I. Holub, All rights reserved.
*
* Tab processing is rather primitive. In particular, it
* assumes that we're using a monospaced font.
*/

int width( c, advance )
int c, *advance;
{
    /* Return the amount of space taken by the character
    * on the output line. Modify "advance" to be the
    * amount of space required to skip past it.
    */

    switch( c )
    {
        case VMOVE:      *advance = 2; return 0;
        case HMOVE:      *advance = 2; return 0;
        case CH_FONT:     *advance = 2; return 0;
        case CH_ATTRIB:   *advance = 2; return 0;
        case ZWIDTH:      *advance = 2; return 0;
        case LITCHAR:     *advance = 2; return 1;
        case SOFT_HYPHEN: *advance = 1; return 0;
    }

    *advance = 1;        /* UP_SPACE and default case */
    return 1;
}

```

(continued on page 112)

C BRICKLIN RUN

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C-scape

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13. Order Entry Screen

Task Definition

Execution Definition

Op	Operation	Type	No.	Description	Assign	Inp	Exp	F
30	Beg. Link	File	2	Customers	Key	1		
31	Sel. Field	R	2	Customer Name		0		
32	Sel. Field	R	4	Customer Discount		0		
33	End Link							
34								
35	Exec. Prog	No.	18	Item List	Parms	2		
36								
37	Upd. Field	No.	8	Customer Discount	Exp	3		
38								
39	Exec. Task	No.	1	Order Lines	Parms	0		

1>Opt 2>Undo 3>Del 4>Add 5>Zoom 6>Expr 7>Draw 8>Task 9>End 10>Help

A Magic PC program looks as simple as this. To design an application you quickly fill-in menu-driven decision tables without having to write a single line of code. For example, just by highlighting the Execute Program operation on this screen and also highlighting the Item List program in the Program Menu, you tell Magic PC to pop-up the Item List window shown in the adjacent screen, when the end-user hits the Zoom key.

Order Entry

Order No: 999 Order Date: 99/99/99 Customer No: 99999 Address: AAAAAAAAAAAAAAAAAAAAAA

Line	Item	Type	Description	Quantity	Unit Price	Total Price
999	99999	A	AAAAAAAAAAAAAAAAAAAAA	-9.999	-999.999.99	-999.999.99

Item List

No.	Description	Type	Price
999	AAAAAAAAAAAAAAAAAAAAA	A	-999.999

Stock Status

In Stock: -999.999
Total Orders: -999.999
Avail to Sell: -999.999

	Order Sum	Discount	Sub-Total	Sales Tax	Order Total
	-999.999.99	-999.999.99	-999.999.99	-999.999.99	-999.999.99

1>Opt 2>Undo 3>Del 4>Add 5>Zoom 6>Expr 7>Draw 8>Task 9>End 10>Help

Magic PC gives you the end-user the power to harness and retrieve data instantly, without any commands or syntax because at runtime you already have built-in options to Add, Delete, Modify, Query and get on-the-spot ad-hoc information simply by highlighting selections from menus. Data validation, security and error-checking are done automatically for you by Magic PC without programming.

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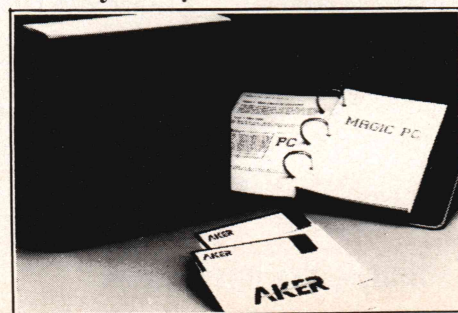
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You're not confined to any particular design sequence as you are with most procedural languages. You can enter and change any Table spontaneously, on the fly, as ideas come to mind and Magic PC automatically maintains the application integrity.

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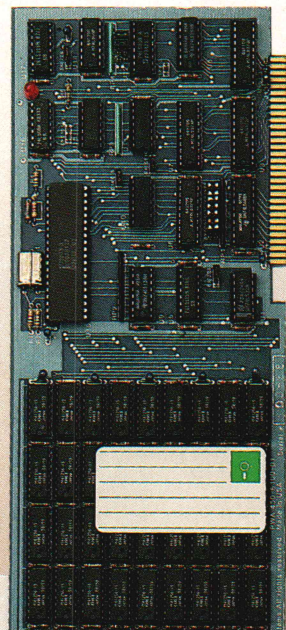
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Listing Twenty-three

(Listing continued, text begins on page 130.)

```

-----*/
dist_to_tab( col )
{
    /* Col is the current column position. Return the
     * distance the next tab set in the Tabstop array.
     * That is, the next tab will be at Tabstop[col + rval].
     * A tab at the current column position is ignored.
     */

    register int    ocol;

    for( ocol = col++; !Tabstop[col] && col < LINLEN; col++)
        ;

    return (col < LINLEN) ? (col - ocol) : 0 ;
}

/*-----*/
field_width( p )
UCHAR *p;
{
    /* Return the distance between p and either end of line
     * or a tab character (\t) or a leader character (SOH).
     */

    register int    count = 0;
    int            advance;

    if( !*p++ )
        return 0;

    while( *p && *p != '\t' && *p != SOH )
    {
        count += width(*p, &advance);
        p += advance;
    }

    return count ;
}

/*-----*/
dotab( str )
UCHAR *str;
{
    /* Expand the tab (^I) and leader (^A - SOH)
     * characters in str to the proper number of tab or
     * leader characters.
     */

```

```

    * Three types of tabs are recognized. (L)eft justifying
    * tabs will print the character following the \t at the
    * tabstop. Right and Centering tabs both use a field
    * width (ie. the number of character following the \t
    * up to, but not including, a following \t or end of
    * line). A centering tab will cause this "field" to be
    * centered on the tabstop. A right adjusting tab will
    * cause the rightmost character in the field to rest
    * immediately to the left of the tabstop.
    */

```

```

int    w;          /* Current field width */
int    d;          /* Distance to next tabstop */
int    col ;       /* Current output column */
UCHAR *p;          /* Current character */
UCHAR *startstr;   /* Original beginning of string */
int    advance;    /* amount to advance past char */

static UCHAR buf[ MAXSTR ];
col = 1 ;
startstr = str ;

/* Copy str into buf with strncpy() and then copy it
 * back expanding tabs an leaders.
 */

strncpy(buf, str, MAXSTR);

for( p = buf; *p ; )
{
    if( !(*p == '\t' || *p == SOH) )
    {
        if( str-startstr >= MAXSTR-1 ) /* out of space */
            break;

        col += width(*p, &advance);

        while( --advance >= 0 )
            *str++ = *p++;

        continue;
    }

    if( !(d = dist_to_tab(col)) )
        break;

    w = field_width( p );

    /* Convert d to the number of spaces to print
     * to get to the specified tab stop. If there
     * are no characters between the current
     * \t and the next \t then just move to the next
     * tab.
     */

```

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```

switch( Tabstop[ col + d ] )
{
case 'R': d -- w ; break ;
case 'C': d -- w/2 ; break ;
}

while( --d >= 0 )
{
if( str-startstr >= MAXSTR )
goto exit;

*str++ = ( *p -- '\t' ? Tab : Leader );
col++;
}

p++;

exit:
*str = 0;
}

```

End Listing Twenty-three

Listing Twenty-four

```

#include <stdio.h>
#include <ctype.h>
#include "nr.h"
#include "nrmap.h"
#include "nrtlen.h"

/*-----
* NRTTEXT.C: Text processing portion of nr
* Copyright (c) 1985 Allen I. Holub. All rights reserved.
*-----*/

typedef CTYPER QUEUE; /* Dummy typedef for queue routines */

/*-----
*-----*/

extern QUEUE *makequeue();
extern CTYPER *show_next();
extern void map(CTYPER*, char*);

/*-----
* Globals:
*
* blankline: Used in outbuf() calls when we need to print
* a blank line.
* Input_queue: Input queue used for line filling. Words are

```

```

*
* enqueued until an entire line is in the
* queue, the the queue's contents are printed.
* Last_queued: Most recently enqueued character.
* Owidth: Space occupied on the output line by the
* characters now in the queue, in units
* (modified by putq() and used in several
* places).
*/

#define QSIZE (MAXSTR * 2)

static CTYPER blankline = NULL;

static QUEUE *Input_queue;
static CTYPER Last_queued;
static int Owidth = 0;

/*-----*/

void text( str )
UCHAR *str;
{
/*Highest-level text processing routine, called
* from process().
*/

CTYPER line [MAXSTR];
static int been_called = 0;

D( printf("text(): working on < %s>\n", str); )

if( Inhibit ) /* Input has been inhibited by an */
return; /* .if or .ie command */

if( !been_called )
{
/* If this is the first time we've been called,
* spring the top of page macro for the first page.
* (all other top of page macros are sprung
* immediately after the bottom line of the previous
* page is printed.
*/

been_called = 1;
do_linetrap( 0 );
TOTRAP = distance();
}

if( TLEN >= MAXSTR )
{
err("Output line too long\n");
}
else if( !*str )

```

(continued on next page)

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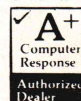
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Listing Twenty-four

(Listing continued, text begins on page 130.)

```

{
    /* A blank line always causes a break use 'sp l if
    * you want blank lines without a buffer flush.
    * Note that outbuf won't print the blank line
    * itself unless spacing is enabled.
    */

    brk(); /* Break */
    outbuf( &blankline, 0 ); /* print the blank line */
}
else
{
    map( line, str );

    if( FILL )
        dofill( line );
    else
        outbuf( line, 0 );
}

if( Itrap > 0 ) /* Input line trap */
{
    if( --Itrap == 0 )
        expand_macro( Itrap_name );
}

/*-----*/

void lt_text()
{
    /* D one-time initializations for this module. This
    * routine is called from main() when the program boots.
    */

    if( !(Input_queue = makequeue( QSIZE, sizeof(CTYPE))) )
    {
        err("Not enough memory for fill buffer\n");
        exit(1);
    }
}

/*-----*/
/* Everything above this point works on char strings,
 * everything below this point works on CTYPE strings. See
 * nmap.c for the mapping routine.
 */
/*-----*/

static int first_white()
{
    /* Return true if the first character in the queue
    * (the one to come out next) is a space.
    */

    CTYPE next = *show_next(Input_queue);

    return( sp_used(Input_queue) && WHITE(next) );
}

/*-----*/

static int putq(cp)
CTYPE *cp;
{
    Last_queued = *cp & 0xff;

    Owidth += CWIDTH( *cp );

    if( !enqueue(cp, Input_queue) )
    {
        err( "Fill buffer full\n" );
        brk();
        return 0;
    }

    return 1;
}

/*-----*/

CTYPE *saveq()
{
    /* Save the current queue contents and flush the queue.
    * Return a pointer which, when passed to a subsequent
    * restorq() call, will restore the queue to its
    * previous state.
    */

    CTYPE *p, *rval;

    p = (CTYPE *) malloc( (sp_used(Input_queue) + 1)
        * sizeof(CTYPE));

    rval = p;

    if( !p )
        err("Not enough memory to save fill buffer\n");
    else
    {
        while( dequeue(p, Input_queue) )
            ++p;

        *p = 0;
        Owidth = 0;
    }

    return rval;
}

/*-----*/

restorq( qp )
CTYPE *qp;
{
    /* Restore the queue to the condition it was in before
    * a previous saveq. p is a pointer returned from a
    * saveq() call. The queue is flushed before it is
    * reloaded from p.
    */

    register CTYPE *p;

    brk(); /* Flush current queue */

    if( qp )
    {
        for( p = qp; *p; putq( p++ ) )
            ;

        free( qp );
    }
}

/*-----*/

prblank( n )
int n;
{
    /* Flush the buffer and print n blank lines. This
    * routine handles the .sp command.
    *
    * If spacing is inhibited (ie .ns was given) do
    * nothing. The nospace test is done in outbuf.
    */

    while( --n >= 0 )
        outbuf( &blankline, 0 );
}

/*-----*/

add_sep( line )
CTYPE *line;
{
    /* If there is something in the queue and that something
    * doesn't start with white space then enqueue an extra
    * space character as a word separator.
    */

    CTYPE c;

    if( sp_used(Input_queue) && !WHITE(Last_queued) )
    {
        c = TO_CTYPE( ' ' );
        putq( &c );
    }
}

/*-----*/

dofill( line )
CTYPE *line;
{
    /* Collect words until we have filled an entire line
    * and then print it.
    */

    int pad; /* Amount of padding needed */
    int tail; /* padding needed on current line */
    int nchars; /* # of chars to print out */
    int prevwidth; /* amount of space used by nchars */
    CTYPE *word; /* beginning of current word. */
    CTYPE *white; /* pointer to beginning of white */
    /* space preceding current word */
    CTYPE *p; /* pointer into hyphenated word. */
    CTYPE *chop_here;
    int extra;
    int addhyphen;

    D( outints("dofill", line) );
    D( printf(">\ndofill: prevwidth=%d, Owidth=%d\n",
        prevwidth, Owidth) );

    if( Num_center )
    {
        /* If we're doing centered lines, output the current
        * buffer without filling.
        */

        outbuf( line, 0 );
        return 0;
    }

    while( *line )
    {
        prevwidth = Owidth;
        pad = U_TLEN - prevwidth;
        nchars = sp_used( Input_queue );
        white = line;

        /* Insert a word into the queue. Add leading blanks
        * first and then the word itself. Putq() increments
        * Owidth as necessary to reflect the amount of
        * space occupied on the output line by the
        * characters in the queue.
        */
    }
}

```

(continued on page 116)

C spoken here...

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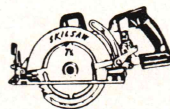
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- is the "howitzer" of Pascals and "could well be the most powerful Pascal compiler ever implemented on a microcomputer" *PC Magazine*, Oct. 29, 1985, p. 144
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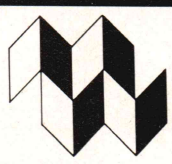
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Listing Twenty-four

(Listing continued, text begins on page 130.)

```

if( CHAR(*line) != ' ' ) /* this is the first word */
    add_sep( line ); /* of an input line */

else while( CHAR(*line) == ' ' )
    putq(line++);

chop_here = word = line;

while(*line && CHAR(*line) != ' ')
    putq(line++);

/* If the new word put more characters into the
 * queue than will fit on the line (U_TLEN) then
 * output everything up to (but not including)
 * the most recently added word. If hyphenation
 * is enabled, output a prefix too.
 */

if( Owidth >= U_TLEN )
{
    addhyphen = 0;
    if( prevwidth > (LINLEN * SPACE_SIZE) )
    {
        err("Line overflow, truncating\n");
        nchars = LINLEN;
    }
    else if( Hyphenate && *word
             && pad > (3*SPACE_SIZE) )
    {
        /* pad = difference between line width
         * and width of line up to the beginning of
         * the previous word.
         */

        hyphen( word, line-1 );

        p = word;
        prevwidth += CWIDTH( TO_TYPE('-') );

        for(;; p < line && prevwidth < U_TLEN; p++)
        {
            prevwidth += CWIDTH(*p);

            if( HAS_HYPHEN(*p) )
            {
                chop_here = p + 1;
                addhyphen = 1;
            }
            else if( CHAR(*p) == '-' )
            {
                chop_here = p + 2;
                addhyphen = 0;
            }
        }

        nchars += (chop_here - word);
    }

    outqueue( nchars, addhyphen );
}

}

}

/*-----*/
brk()
{
    /* Process a line break. If there's anything in the
     * buffer, flush it out. If the adjustment mode is BOTH
     * then adjustment is turned off when the line is
     * flushed (so that the last line of a paragraph looks
     * correct. This routine assumes that the queue always
     * has less than one output lines worth of text in it.
     */

    register int oadj;

    D( printf("Doing break\n"); )

    oadj = Adjusting;

    if( Adjmode == BOTH )
        Adjusting = 0;

    outqueue( sp_used(Input_queue), 0 );

    Adjusting = oadj;
}

/*-----*/
outqueue( numchars, addhyphen )
int numchars; /* # of chars. to dequeue */
{
    /* Output numchars characters from the input queue,
     * using outbuf(). If "addhyphen" is true then the a
     * hyphen is printed at the end of the line.
     */

    register CTYPE *p;
    static CTYPE buf[MAXSTR];
    CTYPE ochar;

    D(printf("outqueue: putting %d characters\n",numchars));

    if( numchars <= 0 )
        return;

```

```

p = buf;

while( --numchars >= 0 && dequeue(&ochar, Input_queue) )
{
    Owidth -= CWIDTH( ochar );
    *p++ = ochar;
}

--p;

/* Delete trailing white space from the output buffer
 * and leading white space from the queue.
 */

while( WHITE(*p) )
    if( --p < buf )
        break;

**p = '\0';

while( first_white() && dequeue(&ochar, Input_queue) )
    --Owidth;

outbuf( buf, addhyphen ); /* Output the line */
}

```

End Listing Twenty-four

Listing Twenty-five

```

# Makefile for Lattice lmk to manufacture nr using
# the Microsoft C compiler, version 4.0
#
CV_CSWITCH = /Zi
CV_LINKSW = /CO /M

CSWITCH =
LINKSW = /NOI /STACK:4096

OBJ1 = nr.obj nrcmd.obj nreg.obj nrexcept.obj nrqlb1s.obj
OBJ2 = nrhyphen.obj nrinp.obj nrmac.obj nrmap.obj nrmsc.obj
OBJ3 = nrout.obj nrprocs.obj nrtab.obj nrtext.obj

#-----
.c.obj:
    cc -c $(CV_CSWITCH) $(CSWITCH) $.c >>err

#-----
nr.exe: $(OBJ1) $(OBJ2) $(OBJ3)
    link $(CV_LINKSW) $(LINKSW) <@<

$(OBJ1) +
$(OBJ2) +
$(OBJ3) +
nr
\lib\tools.lib
<

final: $(OBJ1) $(OBJ2) $(OBJ3)
    link $(LINKSW) <@<

$(OBJ1) +
$(OBJ2) +
$(OBJ3) +
nr
nr
\lib\tools.lib
<

#-----
nr.obj: nr.c nr.h
nrcmd.obj: nrcmd.c nr.h
nreg.obj: nreg.c nr.h
nrqlb1s.obj: nrqlb1s.c nr.h
nrhyphen.obj: nrhyphen.c nr.h nrmap.h
nrinp.obj: nrinp.c nr.h
nrmac.obj: nrmac.c nr.h
nrmap.obj: nrmap.c nr.h nrmap.h
nrmsc.obj: nrmsc.c nr.h
nrout.obj: nrout.c nr.h nrmap.h nrtlen.h
nrprocs.obj: nrprocs.c nr.h
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nrtext.obj: nrtext.c nr.h nrmap.h nrtlen.h
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```

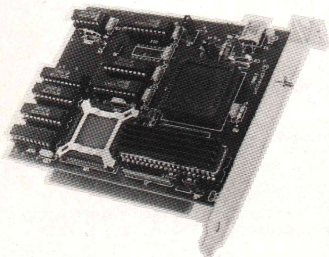
End Listings

(Listing 26 will be in next issue.)

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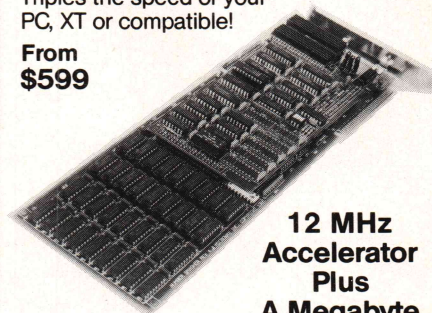
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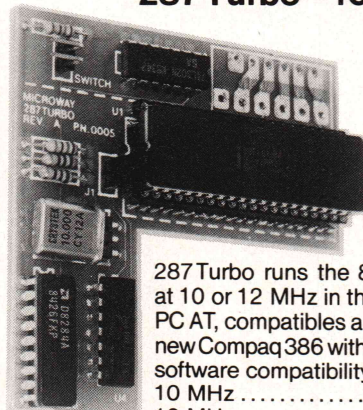
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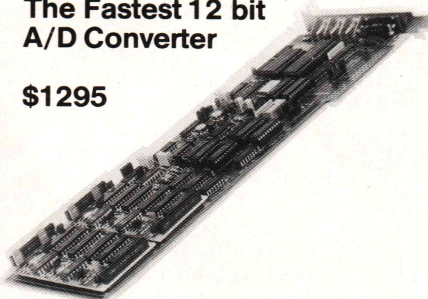
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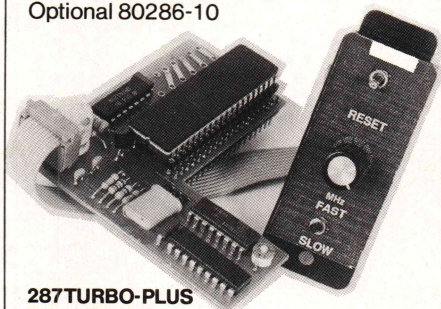
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STRUCTURED PROGRAMMING

Listing One (Text begins on page 140.)

```
( Elemental tools                                     Ham 10:31 12/13/86 )

: -CUR 14 0 SET-CURSOR ; ( no cursor )
: +CUR 6 7 SET-CURSOR ; ( normal cursor )

: BACK ( n - ) 0 ?DO 8 EMIT LOOP ; ( backspace word )

0 CONSTANT NEW ( to collect new digits )
-1 CONSTANT OLD ( to provide existing number to routine )

: INCR ( a - ) 1 SWAP +! ; ( increments variable )
: DECR ( a - ) -1 SWAP +! ; ( decrements variable )

: Bs? ( n - f ) 8 - ; ( T if backspace pressed )
: Cr? ( n - f ) 13 - ; ( T if carriage return pressed )

VARIABLE OK-NEG ( T allows for entry of - ; F rejects - )
VARIABLE SOUND ( T if using sound )

: BELL ( - ) SOUND @ IF 440 8 BEEP ( short beep ) THEN ;

CREATE #PAD 15 ALLOT ( work area )

: #P! ( c n - ) #PAD + C! ; ( stores character c at offset n )

CREATE #VAR 14 ALLOT ( holds various values )

#VAR 0 CONSTANT #DEC ( no. of fractional digits ALLOWED )
#VAR 2+ CONSTANT #dec ( no. of fractional digits ENTERED )
#VAR 4+ CONSTANT #WHOLE ( no. of whole digits entered )
#VAR 6+ CONSTANT #HIT ( no. of keystrokes )
#VAR 8+ CONSTANT NEG- ( T if number is negative )
#VAR 10+ CONSTANT dec~ ( T if decimal point entered )
#VAR 12+ CONSTANT DIGCNT ( counts no. of digits for old nos. )

: PLACES ( n - ) #DEC ! ; ( sets # of decimal places allowed )

: #init #dec 12 ERASE ( don't erase #DEC ) #PAD 15 ERASE ;

: *HIT/NEG #HIT 4 ERASE ; ( resets no. hit and negative flag )

: NEG? ( - f ) NEG- @ ; ( T if number is negative )

: dec? ( - f ) dec~ @ ; ( T if dec point entered )

( Get and edit keystroke                                     Ham 10:33 12/13/86 )

: CAPITALIZE ( c - C ) DUP 96 > OVER 123 < AND IF BL - THEN ;

: FIXUP ( c-c ) DUP ASCII B - OVER BL - OR IF DROP ASCII C THEN
( convert B and space bar to C :- clear number entry )
( L :- 1 ) DUP ASCII L - IF DROP ASCII 1 THEN
( O :- 0 ) DUP ASCII O - IF DROP ASCII 0 THEN ;

: #? ( n - f ) DUP ASCII / > SWAP ASCII : < AND ; ( T if digit )

: BAD? ( n - f ) DUP #? OK-NEG @ IF OVER ASCII - - OR THEN
#DEC @ IF OVER ASCII - - OR THEN
OVER ASCII C - OR OVER Bs? OR SWAP Cr? OR NOT ;

: GET# ( - n ) BEGIN KEY CAPITALIZE FIXUP DUP BAD?
WHILE DROP BELL REPEAT ;

( Collection box                                             Ham 10:34 12/13/86 )

: #,S ( #w - #, ) 3 /MOD SWAP 0- + 0 MAX ;
( takes # of whole-number digits, leaves # of commas required )
( Warning: Assumes 83-Std flag - -1; negate flag if 79 Std )

: FULLCNT ( n - n' ) #DEC @ IF 1+ THEN OK-NEG @ IF 1+ THEN ;
( adds to char cnt the decimal point and minus sign if any )

: BOXSIZE ( n - m ) DUP ( # of digits ) #DEC @ - ( #whole digits )
DUP 1 < ( T if no whole digits ) NEGATE ( 83-Std flag ) >R
#,S ( # of commas ) R> + + 2+ ( space at either end )
FULLCNT ; ( leaves number of character in box )

: BOX ( n - ) BOXSIZE SPACES ;
( prints inverse spaces to define field for number entry )

( Sign/decimal                                             Ham 10:34 12/13/86 )

: -. ( displays - or . or both when no digits yet entered )
NEG? dec? AND IF 3 BACK ." - ."
ELSE NEG? IF 2 BACK ." - ."
ELSE dec? IF 2 BACK ." . ."
THEN THEN THEN ;

( Count digits; show number                                 Ham 10:35 12/13/86 )

: 2, ( d - ) , , ; ( store double into dictionary )

CREATE NINES 9. 2, 99. 2, 999. 2, 9999. 2, 99999. 2,
999999. 2, 9999999. 2, 99999999. 2, 999999999. 2,

: #OFDIGITS ( d - # ) DABS 1 DIGCNT !
BEGIN 2DUP DIGCNT @ 1- 4 * NINES + 2@ D>
WHILE DIGCNT INCR REPEAT 2DROP DIGCNT @ ;
```

```
: PUT# ( - adr cnt ) ( prepares number for display )
0. #PAD 1- CONVERT DROP 2DUP #OFDIGITS >R
<# dec? IF #dec @ 0 ?DO # LOOP ASCII . HOLD THEN
R> #dec @ - #,S 0 ?DO # # ASCII , HOLD LOOP
#S NEG? SIGN #> ;

( Display the number nicely                                     Ham 19:39 12/04/86 )

: DISPLAY# ( n - n ) DUP ( get another copy of max # of digits )
BOXSIZE DUP BACK
( back up to beginning of entry field; top of stack is )
( size of box, which is greater than # of digits )
#HIT @
IF 1- ( space at end ) PUT# ROT OVER - SPACES TYPE SPACE
ELSE SPACES ( new box ) -. THEN ;
( n is max no. of digits to be entered, which stays on stk )

( Wrap-up routine                                           Ham 21:15 11/27/86 )

: 10D* ( d - 10*d ) 2DUP 2DUP D+ 2DUP D+ D+ 2DUP D+ ;

: SCALE# #DEC @ ?DUP IF #dec @ - 0 ?DO 10D* LOOP THEN ;
( scale up to integer from decimal fraction )

: #DONE ( - d # )
( leaves double number entered and no. of digits entered )
( no. of digits - zero means no digits entered )
0. #PAD 1- CONVERT ( leaves addr of 1st nonconverting char )
#PAD - ( number of digits ) >R
NEG? IF DNEGATE THEN SCALE# R> DUP 0-
IF ( number is 0, see whether key pressed or no entry )
DROP #HIT @ 0> NEGATE ( Note: 83-Std flag ) THEN ;

( Adjust counts                                             Ham 18:51 11/06/86 )

: #dec-ADJ #dec @ IF #dec DECR THEN ; ( down one decimal )

: #WHOLE-ADJ dec? NOT IF #WHOLE DECR THEN ; ( down 1 whole no. )

: NO-? ( - f ) #HIT @ 0- NEG? 0- dec? 0- AND AND ;

( When decimal point is hit                                   Ham 18:53 11/06/86 )

: .ROUTINE dec? IF BELL ( decimal point already entered )
ELSE dec~ ON ( mark entry of decimal point )
THEN ;

( Check if need to adjust digits                             Ham 18:23 11/06/86 )

( WHOLE-CK & DEC-CK have this stack diagram: ( n f - n f' )
( where n is the no. of digits entered so far )

: WHOLE-CK dec? 0- IF OVER #DEC @ - #WHOLE @ - OR THEN ;
( makes flag T if dec pt not entered AND we have all the )
( whole number digits that we can accept )

: DEC-CK #DEC @ ?DUP IF #dec @ - OR THEN ;
( makes flag T if we have all the digits to the right )
( of the decimal that we can accept )

( The true flag will cause the latest digit entered to be )
( dropped and the bell to sound (if SOUND is on)

( Count each digit entered                                   Ham 18:24 11/06/86 )

VARIABLE OSTART ( T if starting with whole number zero )

( A starting whole number value of zero is in effect a )
( leading zero and should not be counted in the total of )
( digits entered, or else the final numeric digit will not )
( be accepted. )

: CNT-DIGIT dec? IF #dec INCR
ELSE OSTART @ IF OSTART OFF ( 1-time switch )
ELSE #WHOLE INCR THEN THEN ;

( Initialization for "old" numbers                           Ham 18:26 11/06/86 )

( If old number is decimal, all places are present. )

: SET-dec #DEC @ ?DUP IF #dec ! dec~ ON THEN ;

: SET-NEG ( d n - n d ) ROT ROT ( move dbl to top ) 2DUP 0. D<
IF ( neg: convert and note sign ) DNEGATE NEG- ON THEN ;

( Put number into #PAD as a string of ASCII values: )

: SET-#P ( d - ) <# dec? IF #dec @ 0 DO # LOOP THEN
DIGCNT @ #DEC @ > IF #S THEN #> #PAD SWAP CMOVE ;

( Initializes for loop                                       Ham 18:34 11/06/86 )

: DSET ( d # T| # F -- m n p )
( m - # of digits to collect, n p - limits for loop )
```



```

OSTART OFF #init OVER BOX
IF ( old number present ) SET-dec SET-NEG 2DUP
2DUP OR 0- #DEC @ 0- AND ( double is both zero and whole )
IF OSTART ON THEN ( so mark it as a zero start )
#OFDIGITS #DEC @ MAX DUP #HIT ! ( set # of digits entered )
DUP #DEC @ - 0 MAX #WHOLE ! ( set # of whole digits ent )
ROT ROT SET-#P ( make & save ASCII string )
SWAP DUP 1+ ROT OSTART @ + ( using #3-Std flag to decr )
ELSE ( no old number present ) DUP 1+ 0 THEN ;

```

(Backspace routine Ham 10:35 12/13/86)

```

VARIABLE INDX ( holds index from loop )
: "I" ( - index ) INDX @ ; ( lets me get I from outside loop )
: NO#? ( - f ) #HIT @ 0- ; ( T - no digits entered )
: BSP-ROU ( -- loop-incr ) dec? #dec @ 0- AND
IF dec? OFF 0 ( just backed over the decimal point )
ELSE "I" IF 0 "I" 1- #P! ( zap previous entry in string )
#HIT DECR #dec-ADJ #WHOLE-ADJ ( adjust counts )
NO--? ( no minus sign or decimal point? )
IF BELL "I" NEGATE ( back up all the way )
ELSE NO#? IF "I" NEGATE
ELSE -1 THEN THEN
ELSE *HIT/NEG BELL 0 THEN THEN ;

```

(The above takes care of the details of the backspace in numeric entry & leaves the proper loop increment on the stk)

(Final input word Ham 18:51 11/06/86)

```

: DIGITS ( d # T | # F -- d # ) REVERSE DSET DO DISPLAY# GET#
DUP Bs? IF DROP I INDX ! BSP-ROU
ELSE DUP ASCII - - IF DROP NEG- @ NOT NEG- ! 0
ELSE DUP ASCII . - IF DROP .ROUTINE 0
ELSE DUP ASCII C - IF DROP #PAD C@ ASCII 0 <>
IF #HIT @ NEGATE ELSE 0 THEN #init
ELSE DUP I #P! ( store char ) Cr? IF LEAVE THEN
I 1+ #HIT ! ( count of net keystrokes )
DUP ( # of digits to enter ) I - WHOLE-CK DEC-CK
IF ( at end: reject digit ) 0 I #P! I #HIT ! BELL 0
ELSE #PAD I + C@ ASCII 0 <> I 0<> OR dec? OR
NEGATE ( #3 Std flag ) DUP IF CNT-DIGIT THEN

```

```

THEN THEN THEN THEN THEN +LOOP
DROP ( count ) #DONE REVERSE ;

```

(Test

Ham 18:51 11/06/86)

```

0 PLACES
OK-NEG OFF
SOUND ON
-CUR

```

5 NEW DIGITS

```

CR CR
2 PLACES
OK-NEG ON

```

7 NEW DIGITS

+CUR

End Listing

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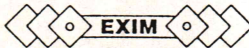
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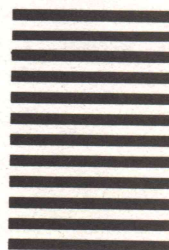
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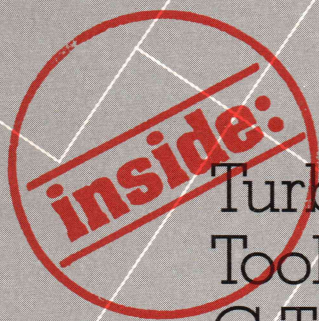
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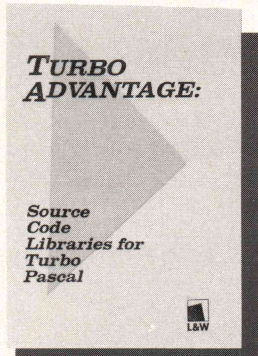
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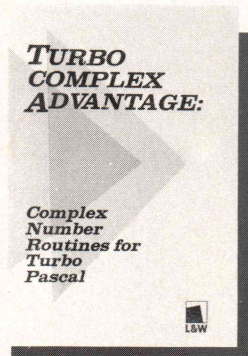
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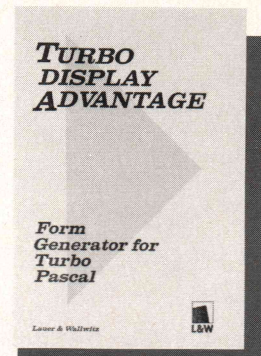
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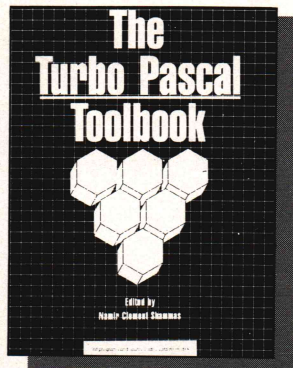
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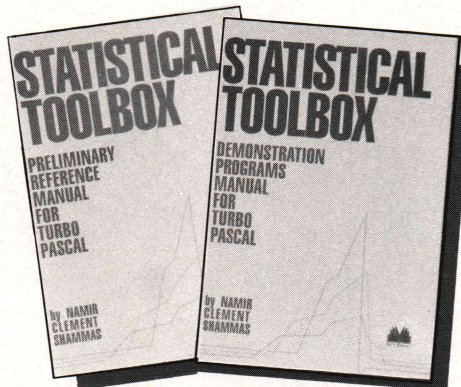
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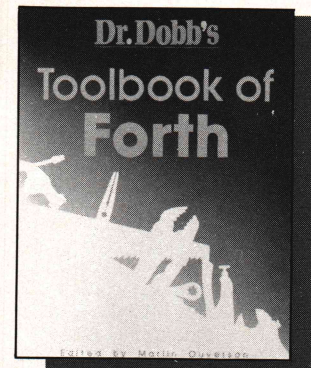
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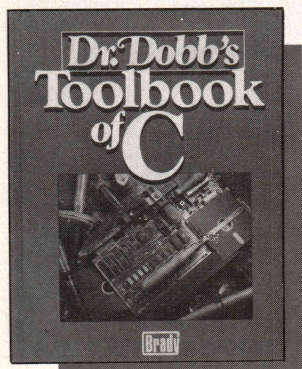
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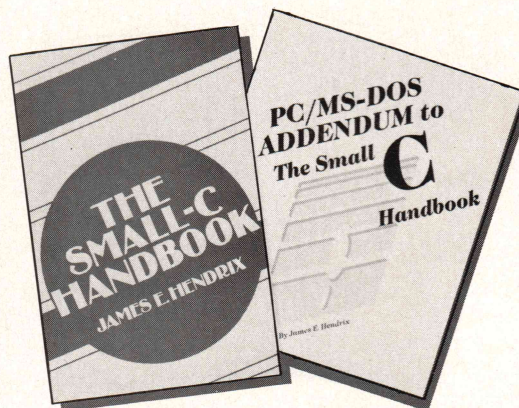
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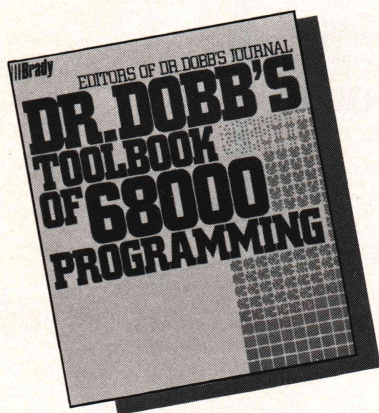
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by David E. Cortesi

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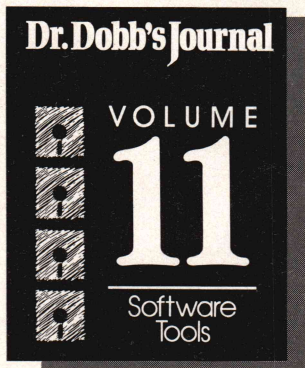
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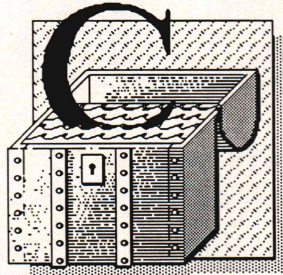
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Nr: A C Implementation of Nroff, Part 3



This is the continuation of the users' manual for nr, my text formatting program. On the source code disk I show how the commands are used by presenting an implementation of the ms macro package. (See the end of this column for information about the source-code disk.)

Tabs and Leaders

Nr supports arbitrary tab stops that can be placed at any column. Tabs are represented in the text with either an ASCII TAB character (Ctrl-I) or with the `\T` escape sequence. Tabs are expanded at input time to the number of space characters needed to get to the indicated column. They don't work very well in proportionally spaced fonts for this reason. Three types of tabs are supported: left adjusting, centering, and right adjusting. The left-adjusting tabs are the normal variety—the text following the Ctrl-I or `\T` is aligned with the next tab stop. Centering and right-adjusting tabs are more complicated. If a tab stop is a centering one, then all text between the next two Ctrl-Is is centered on the next tab stop. Similarly, right-adjusting tabs cause the text to be right-adjusted on the next tab stop. For example, the following two commands clear all the default

by Allen Holub

tab stops and then set up a left-adjusting, centering, and right-adjusting tab in columns 10, 20, and 30:

```
.ta
.ta 10L,20C,30R
```

Given the input:

```
\T!\T!\T!\T
```

```
\Tleft\Tcentered\Tright\T
```

the following will be printed:

```
|           |           |
left        centered    right
```

The vertical bars mark the tab-stop positions.

Leaders are like tabs except that the leader character rather than the tab character is used to pad out the text. The default leader character is a period. You use leaders for things such as tables of contents in which you want a string of dots between the last word in the chapter title and the page number. A leader is signaled by embedding an ASCII Ctrl-A in the text (or by using the `\A` escape sequence). For example, the following sets up a tab stop at column 20 and then prints a table of contents entry with an intervening leader:

```
.ta
.ta 20
Chapter 2 \A 17
```

The foregoing will print as:

```
Chapter 2 . . . . . 17
```

`.ta [A,B, ... Z]`—the argument, if present, is a comma-delimited list of tab stops. Each element of the list can be a specific column, as in `.ta 9,17,25,33`, or an offset from the previous number, as in `.ta 8, +8, +8, +8`. In addition, each number can be followed by one of the following tab types: *R*, for

right-justified; *C*, for centered; and *L*, for left-justified. An example was given earlier. If no tab type is specified, *L* is assumed. If no argument is given, all tab stops are cleared.

`.tp`—print out all the current tab stops in a graphical form:

```
. . . . L . . . . . C . . . . . R . . . . L . .
where the tab positions are marked with an L, C, or R depending on the tab type.
```

`.tc C`—set the tab-expansion character to *C*. The default tab-expansion character is a space. If no *C* is given, tab expansion is disabled.

`.lc C`—change the leader character from a period to *C*.

Control Flow

Though nr doesn't support a fancy control-flow language, it does support *if* and *if...else* mechanisms. The control-flow statements nest. The expression syntax described earlier is also used in an *if* statement, so all the expression operators are available to you here. An expression that evaluates to zero is false; nonzero expressions are true. The basic form of the *if* statement is *if expr action*, where *expr* is any expression involving constants, number registers, and so forth, and *action* is any single dot command or text. For example, in:

```
.if "\n% != 1" .bp
```

the `.bp` will be executed only if you're not on page 1. In

```
.if "\n% == 1" This is the Title
```

the text *This is the Title* is printed only on page 1. You could also use the *if...else* form of the command:

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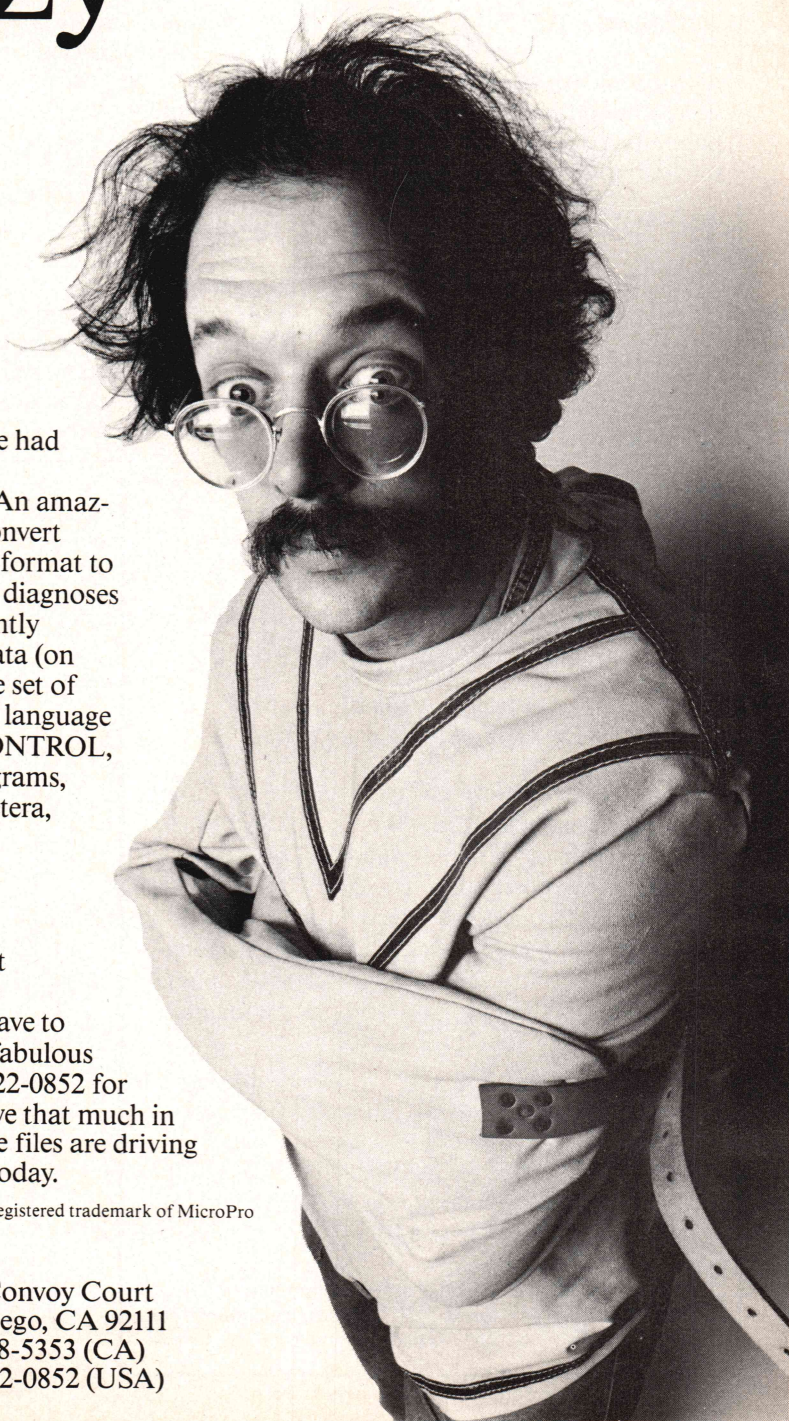
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C CHEST

(continued from page 130)

```
.ie "\n% != 1" .bp
.el This is the Title
```

You can combine several statements into a block using the two block commands (`{` and `}`). For example, in:

```
.ie "\n% != 1" {
    bp
    sp 10
}
```

```
.el This is the Title
```

both `.bp` and `.sp 10` will be executed if you're not on page 1. For `nroff`-compatibility reasons, you can also use the less readable:

```
.ie "\n% != 1" \\\
.bp
.sp 10 \\\
.el This is the Title
```

if you like.

.if condition—a simple *if* statement (that doesn't take an *else* clause). The

expression parser described earlier is used to evaluate *condition*. Two special *conditions* are supported:

.ife action

.ifo action

The *e* evaluates to true if the current page number is even; the *o* is true if you're doing an odd page.

.ie condition—the *if* part of an *if*...*else*. It is otherwise used like an *.if*.

.el—the *else* clause part of the *.ie* command.

`{`—start a block for an *.if*, *.ie*, or *.el*. The `\{` and `\}` escape sequences are mapped to a `{` for `nroff` compatibility.

`}`—terminate a `{` block. The `\}` escape sequence is mapped to a `}` for `nroff` compatibility.

Hyphenation

Nr supports automatic hyphenation, enabled with a `.hy` command and disabled with a `.nh` command. The `nroff .hy` command takes arguments, but the `nr` variant ignores its arguments.

A conservative hyphenation algorithm is used to avoid incorrect hyphens. In addition, only words composed of lowercase alphabetic characters are hyphenated. If the word contains a hyphen, it is always subject to being broken at the explicit hyphen. In general, `nr` won't hyphenate a word if it's not sure what to do. Nonetheless, it does make occasional mistakes. You can put a soft hyphen into the word to tell the program where a hyphen can go—the `\%` escape sequence is a soft hyphen. For example, `nr` will not hyphenate *hyphenate* correctly (it will try to make it *hyph-e-nate*). You can correct this with *hyphen\%ate*. The `\%` is ignored if no hyphen is inserted. If `\%` precedes the word, that word won't be hyphenated. If a word contains a soft hyphen, `nr` will not rehyphenate it.

.hy [N]—enable hyphenation; *N* is ignored.

.nh—turn off hyphenation (turned on with a `.hy` command).

Three-Part Titles

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three-part titles:

`.tl /A/B/C/`—print a three-part title. *A*, *B*, and *C* are strings, where *A* is left-justified, *B* is centered, and *C* is right-justified on the page. Any of these can be omitted, as in:

```
.tl ///page %/  
.tl //-%-//
```

The first character in the string (a / here) is used as a delimiter and can be any character. The title is printed at the current page offset but indent is ignored. The title width is defined with the `.lt` command. A % character is special in a title. It is replaced by the current page number, printed in the current format associated with the % number register. For example, you can produce Roman-numeral page numbers with:

```
.af % i  
.tl //-%-//
```

The `.tl` command is usually used in a top-of-page or bottom-of-page macro.

`.lt [+ -]N`—specify the width of a three-part title, in spaces. Because this command does not affect the `.ll` command, it's possible to have a title with a different width from that of the body of the text.

`.pc C`—change the character used to indicate a page number in a three-part title from % to *C*. This is useful if you want to put a percent sign in the title itself.

Output Line Numbering

`Nr` can automatically number output lines for you—in fact, I use it to generate all the numbered listings 5:for C Chest. You enable output line numbering with a `.nm` command. Note that this command behaves a little differently from the `nroff` equivalent, mostly because I can't figure out how the `nroff` one 10:works. Numbers are printed right-justified in a three-space-wide field. Syntax is `.nm N M S`, where *N* is the number used for the first line, *M* is a line number multiplier 15:and *S* is a string that's printed to the right of each number. The number is printed only when the current output line number is an integer multiple of *M*. When it's 20:not, a filler composed of three space characters is printed instead of the number. This paragraph

was output with `.nm 1 5`:

`.nm N M S`—enable or disable line numbering. If you need to change *M* without changing *N*, use `.nm x M S`, where *x* is any nonnumber. The same goes for `.nm x x S`. You can turn off line numbering by issuing a `.nm` with no arguments. If you want to

***Nr provides
several
mechanisms
other than
the command line
for getting input
or sending output.***

reenable it without resetting the line number, use `.nm x`, where *x* is any nondigit. In addition, the line number used by `.nm` is stored in the pre-

defined *nl* number register.

`.nb [args]`—enable or disable blank-line numbering. Usually blank lines are not numbered—they are output but no number is printed and the output line number is not incremented. A `.nb X` causes blank lines to be numbered too. A `.nb` with no arguments disables blank-line numbering. This command is not supported by `nroff`.

Input and Output

`Nr` provides several mechanisms other than the command line for getting input or sending output to the file or the console:

`.cf file`—copy *file* directly to standard output without any sort of processing. This command is useful for automatically downloading fonts.

`.tm string`—print *string* directly to standard error. One of the uses for this command is to print diagnostics. My version of the `ms` package, for example, prints the page number at the top of each page so you can see

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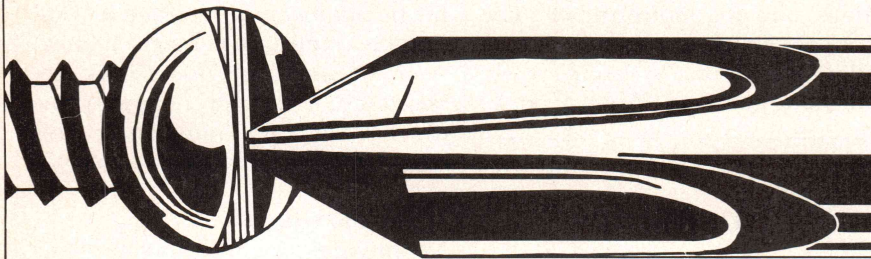
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C CHEST

(continued from page 133)

where you are in the formatting process, even if output's redirected. You have to use `\N` to get a new line into a `.tm` string (as in `.tm page \n%\N`).

.mf macro file—copy the contents of the named macro into the indicated file. This is not an `nroff` command. It's useful primarily for indexes. You can write a macro for collecting index entries, and this macro would automatically append some sort of reference information and the current page number to a special macro every time that it was called. After the entire document has been processed, the macro could then be transferred to a file so that you could modify the data.

.ou string—send *string* directly to the current output, without going through the normal text-processing mechanism. This also is not an `nroff` command. This command is for sending control sequences directly to the printer—that is, for initializations and so on. Use `\x<2 hex digits>` to send nonprinting characters. Note that the `-c` flag (which causes control characters to be printed in readable form) affects the output from this command.

.rd [prompt]—read insertion from standard input rather than from the current input file. Reading stops when two new lines in a row are encountered. This command allows you to insert text interactively into a document. The *prompt*, if any, is printed (and the bell is rung) before any text is read.

.so file—get (source) input from the named file. The position in the current file is remembered, and processing will continue when the source file is exhausted. This command works like an `#include` directive in C does. The `.so` command is replaced by the contents of the indicated file.

Miscellaneous

.\"—signifies a comment. The entire line is ignored. Note that a dot on a line by itself is also considered to be a comment line.

.db [1]—enable or disable debugging mode. A **.db x** enables debugging mode (same as **-v -c** on the command line), and a **.db** without an argument disables debugging mode. This is not an **nroff** command.

.ex—exit back to the operating system just as if input had ended. The end macro is executed.

.ig [xx]—ignore all input until a line starting with **.xx** is found, where **xx** is the argument to **.ig**. In the absence of **xx**, **. .** is used.

.mc string [N]—specify a right margin character, and print *string*, *N* spaces to the right of the current right margin. This usage differs from **nroff**, which uses a single character rather than a string. If no arguments are present, the margin character is disabled. The string is limited to 20 characters (including any spaces implied by *N*). If *N* is missing or 0, 2 is used.

.ml string—print the string at the left margin rather than the right margin (it works like **.mc** does). The page offset must be at least as large as the string, which is limited to 21 characters. This command is not supported by **nroff**.

.wa [N]—wait for about *N* seconds (at most $N + 1$). If *N* is 0 or if no argument is given, a prompt is printed and the program waits for you to type Enter. This command is not supported by **nroff**.

.ws N—enable WordStar-mode output. If *N* is 0 (or missing), WordStar mode is disabled. If *N* is 1, all single new lines are mapped to WordStar soft carriage returns. Note that double new lines, as are used to create a blank line, map to two hard carriage returns. This way you can get a hard carriage return at the end of a paragraph by putting a blank line after every paragraph. An *N* of 2 is handled like *N*=1 except that single carriage returns are replaced with space characters rather than soft carriage returns. Note that you'll also want to do the following:

.po 0 \ " No page offset
.bd \x02 \x02 \ " ^B for bold
.ud \x13 \x13 \ " ^S for underline
.od \x18 \x18 \ " ^X for overstrike

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This command is not supported by nroff.

Escape Sequences

Escape sequences are special sequences of characters that either tell nr to do something or signal some sort of macro expansion (that is, the escape sequence will be replaced by some other text). They are all introduced with a leading escape character. This character is a backslash by default, but you can change it with the .ec C command, where C is the new escape character.

Nr expands escape sequences in three distinct modes: normal mode, copy mode, and nroff copy mode. In normal mode, usually in effect, all escape sequences are expanded. Copy mode becomes active when a macro is being defined—that is, at definition time, the contents of the macro or string are copied into the macro in copy mode. The macro is expanded in normal mode, however. In copy mode only two escape sequences are recognized: \", which introduces a comment; and \ (CR), a backslash at the end of the line, which is a hidden line feed (that is, the current line is merged with the next line). All other escape sequences are just copied into the macro intact. The real nroff has a less restricted copy mode in which all the following are recognized:

```
\ (CR) \" \. \' \$N \nx\n(xx \n+x
      \n+(xx \*x \*(xx \
```

Usually this is more trouble than it's worth because you have to use \ every time you want to get a \ into a macro (to prevent it from being expanded at definition time). You can use nroff copy mode instead of normal copy mode, however. It is enabled with a .cm 1 command and disabled using .cm without the argument. Supported escape sequences are summarized in Table 1, page 137, and are described in depth in the following paragraphs.

\"—introduces a comment. All characters following the \" on the line and all white space preceding the \" on the line are ignored. A \" at the beginning of line is treated as if it were a

blank line (the fill buffer is flushed and a blank line is written to the output). The .\" command, however, causes the line to be ignored entirely (for example, no blank line is printed).

\ (CR)—ignores the end of line—that is, all text on the following line is merged with text on the current line, as if the two lines were one.

\.—a dot that's never interpreted as a command character.

Nr expands escape sequences in normal mode, copy mode, and nroff copy mode.

\ '—a backquote that's never interpreted as a secondary command character.

\|—expands to a backslash.

\\$N—a macro argument, where N is a number in the range 1–9. A macro defined with:

```
.de XX
  arg 1 <\$1>
  arg 2 <\$2>
  arg 3 <\$3>
..
```

and invoked with:

```
.XX "this is one argument" doo wha
will print:
  arg 1 <this is one argument>
  arg 2 <doo>
  arg 3 <wha>
```

*x—expands to the contents of a string named x. Strings are created with a .ds or .as command. Note that the string could also be expanded as if it were a macro (using \.x). Nested * expansions are supported, and the strings can contain other escape sequences (such as \nx).

*(xx—expands to the contents of a *x string having the two-character name xx (works like *x does).

\nx, \n(xx, \n+x, \n+(xx—interpolates number registers, discussed earlier.

\%—indicates a soft hyphen. Soft hyphens are used to indicate places where a word may be hyphenated. If hyphenation is disabled or if the word isn't at the end of a line, then the soft hyphen is ignored. For example, hy\%phen\%ate tells nr to hyphenate hyphenate either after y or n. Words with soft hyphens in them will not be rehyphenated by the automatic-hyphenation algorithm. You can prevent a word from being hyphenated by preceding the first letter with a soft hyphen.

\&c—treats the c as a literal character. Note that this is different from the normal nroff syntax, which treats \& as a zero-width, nonprinting character. Because nr uses several characters whose values are greater than 0x7f internally, \& is the only safe way to get such a character through to the printer. For example, if you need to get a 0x8a to the printer without nroff intercepting it, use \&\x8a. The character following the \& can be any single character or escape sequence that evaluates to a single character.

\ (SP) (a backslash followed by a space)—a nonpaddable and non-breaking space. Given two words separated with a nonpadding space (word\ word), the justification algorithm will never add additional spaces between the words and the two words will always be on the same output line.

\—evaluates to a dash (it's a minus sign in troff).

\/, \^, \0—nr ignores the first two and maps a \0 to a normal space character. These sequences are supported for compatibility with troff, which treats \/ as a thin space, \^ as a somewhat thicker but nonetheless thin space, and \0 as a digit-width space.

\A—a visible leader character. It's the same as a Ctrl-A embedded in the

text.

`\L'Nc'`, `\Nc'`—the two line-drawing functions. `\L'Nc'` evaluates to a vertical line composed of *N* cs stacked one on top of the other. For example, the command `\L'3+'` prints:

```
+
```

The cursor is positioned immediately below the bottom plus sign (you can use `\v` [discussed later] to get back to the top). If no character is specified explicitly, a vertical bar is used: `\L'3'` prints a three-line-high bar.

The `\Nc'` works just like `\L` does

except that a horizontal line is drawn. For example, `\I'20-` draws a horizontal line composed of 20 dashes. The default character is an underscore. Note that you can't use an escape sequence for the line character (as in `\I'10\x85`). You can define a string to do this though:

```
.ds li \I'10\x85'
\*(li
```

`\N`—a new line that can be embedded in a string or `.tm` command.

`\T`—a visible tab character, it is replaced with a Ctrl-I, which will be expanded as the input is processed.

`\a`—a nonexpanded leader character. That is, it's a Ctrl-A that will make it through to the output without being transformed into a series of dots or whatever.

`\d`—sends the cursor down half a line. *N*² can be done with `N\u2\d`.

`\e`—a printing version of the current escape character (the one that was active when the `\e` was encountered in the input). This is more convenient than `\\` because many macros will create other macros on the fly, and each level of secondary macro will also expand backslashes. Sometimes it can take as many as six or eight backslashes for one to make it all the way to the output. A single `\e`, however, is never interpreted as a backslash—it always gets to the output unmolested.

`\fF`—changes fonts. For example, the word *italics* was created with `\fitalics\fP`. (See the description of the `.ft` command for more information.)

`\h'N'`, `\h'Nu'`, `\v'N'`, `\v'Nu'`—give you fine control over cursor motion. The `\h` command is for horizontal motion, and the `\v` is for vertical. *N* is the number of lines or spaces, as appropriate. *N* can be negative. For example:

```
X\h'4'X\h'-1'\v'2'X\h'-5'X
```

prints:

```
X    X
X    X
```

It can be broken up into:

```
X      print an X
\h'4'  move four spaces to the
      right
X      print another X
\h'-1' back up one position (over
      the last X)
v'2'   go down two lines
X      print a third X
\h'-5' back up five spaces
X      print the last X
```

If the character *u* follows the count, then motion will be in terms of vertical and horizontal units, as defined with the `.vd` and `.hd` commands, instead of lines and spaces.

`\o'ab'`—superimposes all characters between the quotes one on top of the other. For example, `\o'0/'` can be used to print \emptyset . Use the special escape sequence `\'` to put a single quote into the list.

Copy mode

`\"` Comment (deletes all following text and all preceding white space).
`\(CR)` Ignore the end of line.

Expanded in nroff copy mode but not in normal copy mode

`\.` A dot that's never interpreted as a command character.
`\'` A backquote that's never interpreted as a command character.
`\\` A backslash.
`\$N` Macro argument, where $1 \leq N \leq 9$.
`*x` String *x*. Nested `*` expansions are supported, and the strings can contain other escape sequences (such as `\nx`).
`*(xx` String *xx*.
`\nx` Number register *x*.
`\n(xx` Number register *xx*.
`\n+x` Number register *x* with auto preincrement.
`\n+(xx` Number register *xx* with auto preincrement.

Expanded only when not in either normal or nroff copy mode

`\%` Soft hyphen.
`\&c` *c* is literal (can be `\xDD`) (nonstandard).
`\(SP)` Nonpaddable nonbreaking space.
`\-` Dash (minus sign in troff).
`\O` Normal space (digit-width space in troff).
`\A` Same as `\A`.
`\L'Nc'` Vertical line of *N* cs (default *c* is `'`).
`\I'Nc'` Horizontal line of *N* cs (default *c* is underscore).
`\N` New line that can be embedded in a string or `.tm` command.
`\T` Same as `\I`.
`\X` Where *X* is any other character, that character.
`\a` Nonexpanded leader character.
`\d` Down a half line.
`\e` Printable version of current escape character.
`\fF` Change to font *F*.
`\h'N'` Horizontal motion by *N* spaces (*N* can be negative).
`\h'Nu'` Horizontal motion by *N* units (as defined with `.hd`).
`\v'N'` Vertical motion by *N* spaces (*N* can be negative).
`\v'Nu'` Vertical motion by *N* units (as defined with `.hd`).
`\o'ab'` Superimpose all characters between the quotes (overstrike).
`\r` Up one line.
`\t` Nonexpanded tab character.
`\u` Up a half line.
`\xDD` Where *DD* is two hex digits, that character.
`\zc` *c* is zero width.
`\{` Start block (see also `.f`).
`\:` Ignored (thin space with troff).
`\}` End block (see also `.f`).

Table 1: *Nr*-supported escape sequences

Flotsam and Jetsam

Declarations and Definitions in One File

The matter of declarations and definitions that I discussed in last month's Flotsam and Jetsam can cause maintenance problems. You can define (allocate space for) a variable in only one place in your program. Nonetheless, you have to declare the variables (with *extern* statements) in every file that uses the variable.

Michael Yam of NYC suggests a solution to this problem: "Managing globals can be messy, particularly in a C program that has many modules. One of the more difficult tasks in a large program is coordinating the variable declarations (the *extern* statements in a .H file) with the definitions (where the space is allocated in a .C file). You can both define and declare all globals in one place by using the C preprocessor, however, thereby making globals easy to track and document. Let's say you have three modules: testmain.c, test1.c, and test2.c. The *main()* subroutine is in testmain.c, which also includes the following statements:

```
#define ALLOCATE
#include "testmain.h"
```

Other files may include testmain.h, but none of these other files includes the *#define ALLOCATE*—that's in testmain.c. Testmain.h holds all global definitions and declarations and looks like this:

```
#ifndef ALLOCATE
#define GLOBAL
#else
#define GLOBAL extern
#endif
```

```
GLOBAL int glob1;
GLOBAL int glob2;
```

```
GLOBAL struct
{
    int x, y, z;
}
world;
```

When you compile testmain.c, *GLOBAL* expands to nothing and the variables are defined (space is allocated for them). In all other modules, be-

cause *ALLOCATE* isn't *#defined*, *GLOBAL* expands to the keyword *extern* and variables are declared.

"I don't think this approach is anything new, but so few programs take advantage of this technique."

Michael's correct in thinking that the technique's not new, but it's certainly useful at times. When you use it, however, be careful of static initializers, which can't be used in *extern* statements. A good solution is to use the variant of the *D()* macro I discussed a few months ago:

```
#ifdef ALLOCATE
#define INIT(x) = { x }
#define GLOBAL
#else
#define INIT(x)
#define GLOBAL extern
#endif
```

```
GLOBAL int x[ ] INIT( 1, 2, 3, 4 );
GLOBAL char *y[ ] INIT( "quick",
                        "brown", "fox" );
```

As before, if *ALLOCATE* isn't *#defined* then the initializations aren't compiled. When *ALLOCATE* is *#defined*,

```
int x[ ] = { 1, 2, 3, 4 };
char *y[ ] = { "quick", "brown", "fox"
};
```

You may need two *INIT* definitions because some compilers won't accept curly braces around single objects, as in:

```
int z = {1};
```

Use:

```
#define INIT2(x) = x
```

Finally you can use a general-purpose initialization macro that includes all the brackets and equal signs with it:

```
#if def ALLOCATE
#define INIT(x) x
#else
#define INIT
#endif
```

You can then say:

```
GLOBAL x[ ] INIT(={1,2,3});
```

C CHEST

(continued from page 137)

\r—sends the cursor up one line.

\t—a nonexpanded tab character (Ctrl-I). Like a *\a*, it will make it all the way to the output without being expanded by the tab-processing routines.

\u—sends the cursor up half a line.

\xDD—gets binary information to the printer. *DD* is two hex digits (two are required). For example, an ASCII escape character can be sent to the printer with a *\x1b*.

\zc—says that *c* is a zero-width character. For example, *â* can be printed with *\z^a*.

\{, \}—form a block in an *.if*, *.ie*, or *.el*. For example, in:

```
.if( \nx ) \{
.in +10
.ti -10 \}
```

both the *.in* and *.ti* are executed if *\nx* contains a nonzero number. The *\{* and *\}* are supported primarily for nroff compatibility. The *nr* commands *{* and *}* tend to be more readable:

```
.if( \nx ){
.in +10
.ti -10
}
```

Availability

The February, March, and April 1987 C Chests have been combined in *Nr: An Nroff-Like Text Processor for MS-DOS*. This reprint is available with a source-code disk for \$29.95. Send prepaid orders to M&T Books, 501 Galveston Dr., Redwood City, CA 94063 or call (415) 366-3600, extension 216. Please add \$2.25 for shipping and handling (\$5 for foreign orders).

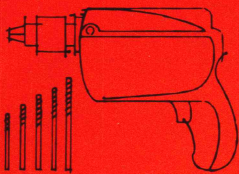
Missing Subroutines

The subroutines *newsample()*, *running_mean()*, and *deviation()* were referenced in February but will be published in the May listings. The *ferr()* subroutine was referenced in February and published in March (page 48). The *err()* subroutine is just *ferr()* without the *exit()* call.

DDJ

(Listings begin on page 84.)

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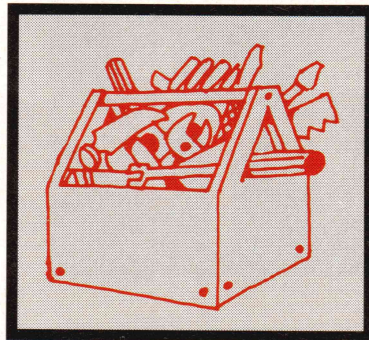
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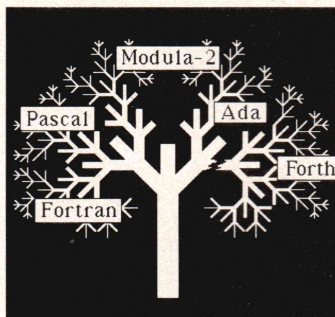
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People in Programming



Programming begins with people and their problems: a good program is a sound solution that the user likes. The initial problem in programming is not communicating with the machine but with the client. Discovering what the client wants and—more important—what the client needs, helping the client understand trade-offs and alternatives, and in general learning enough about the client and his or her relationship with the problem so that the program is born with the greatest chance of success—all this requires techniques that do not fold neatly into algorithms.

Programmers sometimes come to grief not because of their lack of technical skills with the hardware and the software but because of misunderstandings and imperfect compromises with the people involved.

You might be interested in two books that seem particularly interesting and helpful in extending skills in the people direction. The first is *Getting to Yes*, by Roger Fisher and William Ury (Boston: Houghton Mifflin, 1981). This is the only book on negotiation I have seen that describes a method instead of offering only a potpourri of unrelated tactics. Not only does it provide a method but it also gives a rationale that demonstrates both the effectiveness and the legitimacy of the techniques.

Negotiation is a primary people skill in programming. Who has not encountered a client whose desires exceed the budget or whose whims

sional programmer's approach is either to do slavishly whatever the client asks, however inefficient or dubious, or to implement the programmer's own ideas, arrogantly ignoring the wishes of the client. The professional, on the other hand, recognizes the importance of educating the client and negotiating a sound solution.

Besides negotiating on the technical aspects, programmers (particularly freelance programmers, whose every job involves a contract) must be competent at blunt business negotiation. *Getting to Yes* is as close to a complete manual of negotiation as you can get, with application in every area of negotiating.

The key to successful client relations involves more than a sound technical solution in the context of a well-negotiated agreement. The relationship is woven from a myriad of daily exchanges, with the resulting fabric called cooperation. *The Evolution of Cooperation*, by Robert Axelrod (New York: Basic Books, 1984) provides a computer context for this elemental mode of human exchange.

The book describes two tournaments in which programs were developed to play out strategies of cooperation (or noncooperation) in a prisoners' dilemma situation: in which mutual betrayal gets nothing, but one betrayal gains significant advantage over mutual cooperation and being betrayed gets nothing or little. The explorations are intriguing. You cannot push too far the social analogies of computer strategies, but playing with the ideas is at least

stimulating, especially since the strategy that won the two tournaments has a long and honorable history.

Number Input

In my inaugural column (July 1986), I proposed a number-input word to collect numbers calculator-style, displaying appropriate punctuation, tolerating normal user errors, and giving the programmer control over the number of digits that can be entered before and after the decimal point.

Other languages (notably C) come provided with a toolbox already stocked with useful routines such as number input. Forth instead offers to its programmers the elements from which they can build tools. Over time, Forth programmers accumulate a collection of handmade tools, often beautifully worked to fit precisely the special nature of their particular applications. Moreover, because he or she built the tool, the programmer understands exactly not only what it does but also how it does it—the limitations and the strengths—and can readily modify the tool to fit any mutation of the original situation.

The drawback to Forth's approach is that building and polishing the tools take time. Sometimes it would be nice to take a close-enough solution off the shelf instead of fashioning the perfect fit to the specific problem. One source of such solutions is the set of modules written in other languages—C or FORTRAN, for example—that have a store of existing tools. Laboratory Microsystems has recently published a Forth, which it calls UR/Forth, that can be linked to such alien modules.

Another approach is to augment your collection of software tools by reading (and adapting) published tools. Here I discuss my current solution to the common problem of collecting a number from the key-

by Michael Ham

overburden the hardware? The programmer often must tactfully devise and suggest practical alternatives to wishful thinking and then negotiate for their acceptance. The unprofes-

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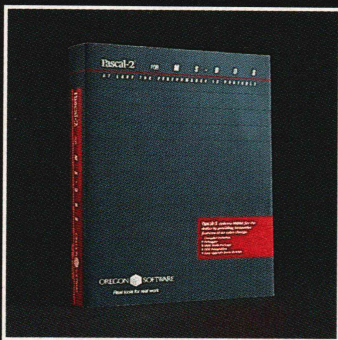
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STRUCTURED PROGRAMMING (continued from page 140)

board—the word *DIGITS* (see Listing One, page 118). This word leaves two numbers on the stack—the number entered (as a signed double-precision number) and above it the count of the digits entered. Decimal fractions are scaled to integers, and the decimal display is merely cosmetic—for example, the number displayed as 0.0023 is in fact stored as a double-precision 23.

The count of digits distinguishes an entered 0 from the 0 that results from no entry. “No entry” results from the user pressing Return when the entry field is blank. I designed “no entry” to leave a double-precision 0 on the stack because I like my general-use tools to leave the same number of arguments under all conditions.

The count of digits has some other uses. If the count is less than 5, for example, the entered number is less than 10,000 and thus the top cell of the double-precision number will be 0, which can be dropped to leave a single-precision version of the entry.

Most of the complexities in the word are because of various special cases. Each of the following revealed a bug during the development of *DIGITS*:

- pressing a clear-entry key (C or B or the space bar) when the entry is already clear
- starting with an old number equal to 0
- having fewer nonzero digits in the number than the number of decimal places entered

When you start with an old number of 0, the single 0 digit must not be counted as you begin to enter numbers. If it is counted, you will be able to enter at most one fewer digits than you should because the keystroke count routine will be initialized to count what is in effect a leading 0: the 0 that was the old number.

The number of nonzero digits in the number can be less than the number of decimal places entered (for example, 0.0023 has four decimal places entered but is represented as the two-digit number 23). The difference between the number of digits in the number and the number of digits to

the right of the decimal can thus be negative. It is for this reason that you see 0 MAX in computing the number of commas.

Another minor complexity results from the incomplete complement of double-precision operators provided by most Forths. My January column suggested a naming scheme for arithmetic operators. In terms of those names, this application could use the two operators $M \cdot D$ (a double and a single factor, single on top, giving a double product) and M/D (a double dividend, a single divisor, and a double quotient). The pair D^* (two doubles as factors with a double product) and $D/$ (a double dividend and a double divisor giving a double quotient) would serve equally well.

With $M \cdot D$ (or D^*) the routine could accumulate the number as a double: each time a digit is entered, the number so far entered would be multiplied by 10 and the new digit added. With M/D (or $D/$) the backspace would be easy to implement by dividing the number so far accumulated by 10 to strip off the last digit entered.

One approach is to write definitions for these operators. I use an alternate route: I accumulate the number as a string of ASCII characters and use *CONVERT* whenever I want the value of the number.

I'll briefly discuss the code, but let me first point out that I do some arithmetic with the flags. Deplorable as the practice may be, I find it irresistible. The important thing for you to know is that these are 83 Standard flags, in which true is shown by -1 (all bits on), unlike the 79 Standard true, which is 1. Thus I use the (83 Standard) flag to decrement or (after negating it) to increment a count. The sign must be reversed if you are using 79 Standard flags.

This code may be more complex than necessary: simplicity is not easily achieved. The code does, however, get the job done, and the response time (on an IBM PC) is totally adequate. Share with me any simplifications you discover.

The first few definitions are tiny tools. You will note that the words to turn the cursor on and off are vendor dependent, and you should check with your own Forth for this type of control. Some Forths automatically extinguish the cursor when *KEY* is ex-

ecuted; this was written in Laboratory Microsystem's PC/Forth, which does not. I use `-CUR` to turn the cursor off, `+CUR` to turn it back on.

The function of the phrase `8 EMIT` is also vendor dependent: some Forths execute a backspace, some display a character. So you may have to revise the definition of `BACK` to make it work as intended: to backspace the cursor as many positions as specified by the number on the stack.

Some definitions, such as `NEW` and `OLD` and `Bs?` and `Cr?`, are nonce words to improve the readability of the code, always an important objective. As usual, I prefer short definitions based on normal English usage. In my eyes, playfulness is more an asset than a detriment, provided that the word's name reflects its effect.

Control of the sound generator is also vendor dependent. In the definition of `BELL`, the stack holds numbers that define the pitch and the duration. I prefer a short beep. The variable `SOUND` provides an easy on/off control for beeping.

Because `PAD` was occupied with other tasks, I created a separate work area for the number being entered. This work area, `#PAD`, will contain the string of ASCII characters that represent the number.

`#VAR` is an array in which I name each cell using a constant. The constant, returning the address that is its value, acts as a variable name. Some naming conventions are apparent: a name ending with `~` is a Boolean variable; a named prefixed with `*initializes` an array or variable by setting it to zero. (I read `*as` "zap.")

The words that collect and edit the character typed have some points of interest. You will note that `FIXUP` converts B or blank to C. C clears the display, and B and blank become synonyms. Also, L and O are converted to 1 and 0, respectively; the user's intention is clear, and overpunctilious programs quickly make enemies.

The word `#?` checks whether the ASCII value is in the range for a decimal digit. `BAD?` leaves a flag (denoted by the suffix `?`) that is true if the entry was bad. Because Forth is not typed, I can use as a flag the value from `#DEC` (the number of places to the right of the decimal). A 0 from `#DEC` (that is, there are no places to the right of the decimal) acts as a false flag; any other

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value (that is, there are places to the right of the decimal) acts as a true flag. The decimal point is thus allowed as a valid character only if `#DEC` is greater than 0.

The word `#,S` computes the number of commas required, given the number of whole-number digits. If the number of whole-number digits is a multiple of 3, the computed comma count is corrected by decrementing it by 1 (using the 83 Standard true flag of `-1`). The phrase `0 MAX` corrects for those instances in which the number of nonzero digits entered minus the number of places to the right of the decimal is negative, thus producing a negative quotient.

`FULLCNT` adjusts the character count of the number of digits and commas to include the decimal point and minus sign (if they are allowed). `BOXSIZE` uses this word to calculate from the number of digits being collected how large a box will be needed: as many spaces as the maximum

number of printable characters, plus one space at either end of the box. Because the inverse video on the color screen clips the edges of some characters, I include an extra space at the beginning and end of the number display.

`BOXSIZE` has one tricky aspect: because I print the leading 0 for decimal fractions less than 1 (for example, 0.0023 instead of .0023), I have to add 1 to the character count if I am collecting such a fraction. I save on the return stack the flag that tells me whether this is that sort of fraction. The flag, after correcting the sign, is added to the count. `BOX` then uses `BOXSIZE` to print an inverse field in which the number will be entered.

One peculiarity in number entry is that some data must be displayed before any number has been entered at all: the minus sign and the decimal point could be the first two keystrokes, and when those are entered, there is still no number to edit. The word `-.` displays these characters. You will note, by the way, that the minus key works as a toggle so that

the minus sign can be entered or altered at any time during number entry.

`PUT#` prepares the accumulated number for display, leaving on the stack the address and count of the string, which is then displayed in `DISPLAY#`. `?DO` is found in most Forths: it executes the loop only if the two arguments are unequal. If your Forth lacks `?DO`, you can substitute `2DUP = IF 2DROP ELSE DO` for it and follow `LOOP` by `THEN`.

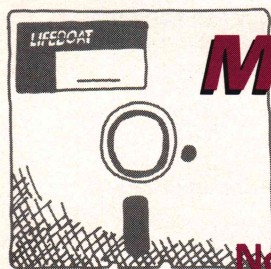
When number entry is complete, the number is left on the stack with any decimal fractions scaled up to an integer value. It is the programmer's responsibility to make sure that the size of the entries allowed (total number of digits, number of decimal places) will result in a number that will fit within the bounds of a double-precision number after scaling.

`SCALE#` takes care of the situation in which the user did not enter all the fractional digits allowed. If the entry parameters allowed for thousandths (three fractional digits), for example, and the user pressed Return before entering a decimal point (or any digits after it), `SCALE#` will multiply the entered number by 10 three times in order to force the three fractional digits (0s in this case). The word `10D*` fakes a double-precision multiply by 10.

The count adjustments in the next group take care of decrements required when backspacing (deleting digits). The words `WHOLE-CK` and `DEC-CK` check the limits imposed by the programmer on the number of digits that can be entered as whole number digits and the number of digits that can be entered as fractional digits. Attempts to transcend the programmer-imposed limit are rejected.

`SET-NEG` sets the negative variable when an old number is entered. Note that the number is accumulated as a positive number, with the actual sign indicated by the variable `NEG~`.

`DSET` sets up everything to start the loop and leaves on the stack the loop limits and the number of digits to collect. When you are collecting a new number, the loop limits are `m+1` (one more than the number of digits to collect) and 0, but if the routine starts with a number already entered, then the limits are adjusted appropriately. The upper limit is `m+1`



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because the user must be able to enter one more keystroke than the number of digits to collect. Typically that one additional keystroke will be a Return, but it might be a backspace. Any other final keystroke is rejected.

Because the topmost word *DIGITS* is so complex, I wanted to factor out some subroutines to improve readability and comprehensibility (and therefore debugging). But then I had to be able to access the index value from a word outside the loop. The simplest solution was to store the index value into a variable and define the word "I" to fetch the variable's value. This would have been a natural place for a *QUAN*, but most Forths don't have them.

You will note that *DIGITS* is a *DO...+LOOP* structure. This structure seemed the easiest way to move back (backspacing) and forth (entering a valid character) in the entry or just to remain in place (attempting to enter an invalid character): by having the index increment be negative, positive, or 0, respectively.

The backspace routine, by the

way, has to keep track of whether the backspace is over a digit, the decimal point, or the minus sign, or disallowed because no valid character has yet been entered to backspace over. The variety of situations tends to complicate the definition. *BSP-ROU* leaves the appropriate increment to the loop index. When this is the negative of the current index value, the loop returns to its starting point.

DIGITS keeps on the stack the number of digits to be entered because that number is periodically referenced. It would perhaps have been cleaner to park that number inside one of the pseudovariables that make up *#VAR*, but by the time the idea occurred to me, the routine was already working. Once the routine was working, I was disinclined to toy with it.

I suggest that, as an exercise, you modify the routine so that it stashes the number of digits to be entered into an additional cell in *#VAR*, whence it is fetched when needed. When you have the revised routine working once more, you should have

a good understanding of this tool, which I hope proves useful to you.

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(Listing begins on page 118.)

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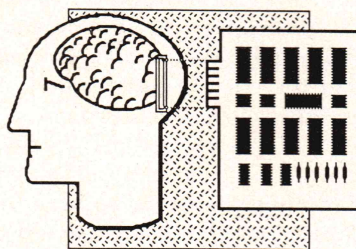
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Object-Oriented Programming in AI



This month I continue the theme of object-oriented LISPs by focusing on three object-oriented extensions to Common LISP: ObjectLISP, New Flavors, and Common-Loops. Although it is unlikely that any of these precise implementations will become a standard, any such standard will probably combine features of all three.

ObjectLISP

ObjectLISP is the candidate for an object-oriented extension to Common LISP that was offered by LISP Machines. Although it does not now look as though it will provide a substantial part of the standard currently being defined, it is a relatively easy system to understand and has several commendable features. One of the distinctive features of the ObjectLISP approach is eliminating any special syntax for message sending so that object-oriented methods are invoked with essentially the same syntax as any Common LISP function. Another important feature is that ObjectLISP departs from most other object-oriented systems by deliberately making the relation of a class to a subclass the same as the relation of a class to an instance. What this means on the implementation level is that the nesting of closures is used for both specializing and instantiating classes. When combined, as they are in ObjectLISP, these two features result in a simple and streamlined system so that class variables, class functions,

by Ernest R. Tello

instance variables, and instance functions all exhibit the same basic behavior. One of the byproducts of not differentiating between an instance and a class is that, during development, you can use a class as a prototype instance or an instance as a prototype class.

ObjectLISP also has the convenient feature, often not present in object-oriented systems, of allowing the dynamic creation and modification of objects on the fly, as it were, while programs are running. Also, all inheritance operates dynamically. This means that changes in the state of a superclass of an object that are inheritable will do so right when the changes occur.

The basic ObjectLISP system is based on five primitive functions: *make-obj*, *kindof*, *ask*, *have*, and *defobjfun*. Creating an object can be as simple as writing:

```
(setq business (make-obj))
```

Frequently, though, the object will be a specialized version of another object that already exists. In this case, an object is created with something such as:

```
(setq wholesaler (kindof business))
```

The *ask* function is used to evaluate a Common LISP expression in a particular object's environment. The *have* function creates variable bindings that are local to objects. These functions are usually used together in ObjectLISP to declare class variables and instance variables. This could be done for the *business* object just created like this:

```
(ask business (have 'type-of-activity
                    'economic))
```

This can then be checked to make sure it has been accepted by the system. If you do so, the terminal screen might read:

```
(ask business type-of-activity)
economic
```

The *defobjfun* function is used to define Common LISP functions that are bound or assigned only to a particular object or class of objects. Continuing with the example I have been using, I might say:

```
(defobjfun (calc-net-gain business)
            (gross-sales costs)
  (setq net-gain (- gross-sales total-costs)))
```

The ObjectLISP syntax for calling such a function can be illustrated by:

```
(ask business (calc-net-gain 500 300))
```

Another important capability of ObjectLISP is the ability to create shadowed functions. This is a way in which the inherited functions can be used to create more specific versions of the function for more specialized objects. In many cases, the way this can be done efficiently is by adding only the more specialized parts and then making a call to the inherited function.

Although there is no real difference between an instance and a subclass in ObjectLISP, in practice it is convenient to have a way of using an object as a template for creating other instances of it. One way of doing this is to define an *exist* function for that object as shown in Example 1, page 147. With *exist* functions of this kind, it becomes much easier in ObjectLISP to define instances of objects. So, for example, you could define several business instances as follows:

```
(setq unicom (kindof business))
(ask unicom (exist))

(setq softrend (kindof business))
(ask softrend (exist 'ownership-type
                    sole-proprietor))
```


In ObjectLISP, an object is really a list of frames. The first member of the list is its innermost frame, the original bindings supplied to it when it is created. The remaining elements of the list are all the elements that it inherits, appearing in the order in which it inherits them.

Multiple inheritance in ObjectLISP is accomplished by supplying multiple arguments to the *kindof* function. So, for example, if you have also defined an object called *adversary*, then you could define a class called *competitor* using multiple inheritance as follows:

```
(setq competitor (kindof business
                        adversary))
```

At this point, ObjectLISP does not appear to be one of the winning contenders for the standard, partly because it uses dynamic binding but also because it is a new approach that still has not been tried and proven for any appreciable time. Because there are still some difficult and controversial issues in object-oriented LISP, I think that some of the aspects of ObjectLISP, particularly the placing of classes and instances on a common footing and the ability to modify objects on the fly, deserve some serious consideration.

Old and New Flavors

As I said in my last column, the original Symbolics Flavors system was the first commercial object-oriented extension to LISP to gain relatively widespread popularity and to prove the

extreme value of object-oriented LISP in practice. The latest software release for the Symbolics 3600 series machines, Genera Release 7.0, now includes New Flavors, the candidate from Symbolics for the object-oriented standard for Common LISP. Symbolics Flavors grew out of the Flavors system developed by the MIT LISP Machine group back in 1979. By 1981, the Symbolics software group had developed a more efficient Flavors system, an object-oriented system that has come to be a favored programming approach both for much of the in-house systems programming at Symbolics and for numerous AI projects carried out by users.

New Flavors represents an attempt to overcome some of the weaknesses encountered by users of the Symbolics Flavors system during the five years of its existence. David A. Moon of Symbolics recently outlined the main goals of New Flavors as follows:

- to encourage greater program modularity
- to facilitate writing large, complex programs
- to provide favorable run-time performance
- to maintain downward compatibility with old Flavors

Like the original Flavors, New Flavors uses the *defflavor*, *defmethod*, and *make-instance* functions for creating objects and procedures. The way the example introduced in the discussion of ObjectLISP would be

coded in New Flavors is shown in Example 2, below.

One of the central ideas in New Flavors is the notion of generic functions. The main point of this is to allow distributed definition of functions as well as multiple inheritance of properties. This means both having the same name for a method that varies depending upon the class to which it is bound and being able to use parts of code from various different objects. Toward this end, the *defgeneric* function has been provided.

In New Flavors, generic functions have the same syntax as do nongeneric functions. This has the advantage that any function that is a caller of another function does not need to know which to specify. Other advantages are that all debugging and utility functions designed to work with ordinary Common LISP functions can also work with generics.

New Flavors has adopted a clear set of rules for ordering flavor object components. *Components* are all parts of an object, both those declared directly and those that are inherited. The three rules that are followed are:

- The flavor's own binding always precedes those of its components.
- The local order of components of flavors always adopts the order stipulated in the *defflavor* declarations.
- All duplicate flavors are automatically removed from the sequence.

Method Combination

As I've mentioned before, Flavors

```
(defobjfun (exist business) (&rest args &key*
  (name 'no-name-yet)
  (location 'no-location-yet)
  (industry 'no-industry-yet)
  (business-type 'no-bus-type-yet)
  (size 'no-size-yet)
  (year-founded 'no-year-founded-yet)
  (ownership-type 'no-ownership-type-yet)
  (market-share 'no-market-share-yet)
  &allow-other-keys)
  (have 'name name
    'location location
    'industry industry
    'business-type business-type
    'size size
    'year-founded year-founded
    'ownership-type ownership-type
    (apply 'shadowed-exist args)
  ))
```

Example 1: Defining an exist function in ObjectLISP

```
(defflavor business
  (name location industry business-type size
  year-founded
    ownership-type market-share) ()
  :readable-instance-variables
  :writable-instance-variables
  :inittable-instance-variables)

(setq unicom
  (make-instance 'business
    :name unicom
    :location santa clara
    :industry computer
    :business-type software
    :size 18
    :year-founded 1976
    :ownership-type private
    :market-share 11.3

  (defmethod (calc-net-gain business) (gross-
    sales costs) (- gross-sales costs)))
```

Example 2: Creating objects and procedures with New Flavors

was the first object-oriented system to provide the form of abstraction that allowed different parts of the code for functions to be mixed in modular fashion just as complete methods and variables may be inherited. Various built-in combination methods are provided for this purpose. So, for example, programmers can choose between such method-combination modes as:

- calling only the most specific method available in the hierarchy
- calling all the methods in order of specificity, either upward or downward
- trying each method in turn, starting with the most specialized, until one is found that does not return nil

There are also several other built-in combination-method modes.

In addition to defining new methods and selecting built-in combination-method types, programmers can also define new combination methods using the define-method-combination and define-simple-method-combination functions.

Development Tools

New Flavors provides various facilities for inspecting the current state of an object-oriented system under development. You can either invoke them by entering commands or by pointing the mouse at the names of various items on the display. So, for example, you can view either the subclasses or superclasses of a cur-

rent flavor, and you can view all the instances of a given flavor that are currently alive. These are some of the really useful facilities that an object-oriented system needs if it is to be used for serious AI applications. Despite its lush user environment, some of these features are absent even in Smalltalk.

CommonLoops

The object-oriented extension that has been developed at Xerox PARC has several definite goals and key concepts. It is not surprising that, of all the systems discussed here, it has the most in common with Smalltalk because the amount of expertise present at Xerox with this type of object-oriented system is still considerable. But CommonLoops also represents a departure from Smalltalk in that it offers a clear philosophical vision of how object-oriented programming can be fitted most naturally into the Common LISP dialect and in a way that preserves the greatest amount of generality. It is therefore intended to provide a basis for as many as possible of the serious approaches to object-oriented AI. One of the stated goals of CommonLoops was to provide a general kernel, written in Common LISP, from which any of the major object-oriented systems in use today, such as Flavors, Smalltalk-80, and Loops, could all be implemented. Like Smalltalk, therefore, CommonLoops makes use of the metaclass protocol to implement its class hierarchy system.

The Kernel

The direction taken by Common-

Loops is to use an option to the *defstruct* construct in Common LISP in order to define classes. The *:class* option to *defstruct* is employed by CommonLoops to specify the metaclass that will be used in the system to determine how the object-oriented approach to be implemented will behave. The standard metaclasses provided in CommonLoops are *built-in-class*, *structure-class*, *list-structure-class*, and *vector-structure-class*.

As does Smalltalk, CommonLoops has various built-in classes. This means that even before a programmer defines any classes, there are already various ones present that describe the behavior of the system. Example 3, below, shows the hierarchy of CommonLoops' built-in classes, shown as they might appear in a "class browser," with the type of class represented in parentheses to the right.

Through this hierarchy of metaclasses, CommonLoops controls the way that the options to *defstruct* determine the form of object-oriented system that will be present. The *structure-class*, for example, is the default class that *defstruct* uses when no *:class* option is specified. The classes that are then created default to a structure that acts like the ordinary *defstruct* in Common LISP. *Abstract-class* is used in the *:class* option for classes that will not themselves be instantiated but act as placeholders in the hierarchy—for example:

```
(defstruct (business (:class
                      list-structure-class)))
```

Table 1, left, gives a list of the main CommonLoops primitives.

Multiple Inheritance

Specifying inheritance from multiple classes is accomplished in CommonLoops through an extension of the *:include* option of *defstruct* to allow it to accept a list of names of classes. Following the same example that I have been using to illustrate multiple inheritance, the *competitor* class, which inherits from the two parent classes *business* and *adversary*, would be implemented in the following way in CommonLoops:

```
(defstruct (competitor (:include
                        business adversary)))
```

```
t      (abstract-class)
object  (class)
  essential-class ''
  abstract-class ''
  built-in-class ''
  class ''
  structure-class ''
  list-structure-class ''
  vector-structure-class ''
number  (abstract-class)
  integer ''
  fixnum (built-in-class)
sequence (abstract-class)
  list ''
  cons (built-in-class)
```

Example 3: The hierarchy of CommonLoops' built-in

```
classes
class-of
defmethod
get-dynamic-slot
get-function
get-slot
mlet
ref
remove-dynamic-slot
remove-method
run-super
specialize
with
```

Table 1: Main CommonLoops primitives

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Multimethods

One of the most important innovations in CommonLoops is that of multimethods—procedures that are, in effect, messages sent to any number of objects of different types. So instead of defining the method *draw-at*:

```
(defmethod (rectangle :draw-at) (upper-left-x upper-left-y  
                                lower-right-x lower-right-y)  
  (draw-box upper-left-x upper-left-y lower-right-x  
            lower-right-y))
```

as you would in Flavors, in CommonLoops you would write it:

```
(defmeth draw-at  
  ((r rectangle) (upper-left-x integer) (upper-left-y integer)  
   (lower-right-x integer) (lower-right-y integer)  
   (draw-box upper-left-x upper-left-y lower-right-x  
             lower-right-y))
```

In this definition, the first argument to *draw-at* is *r*, which is declared as of the class *rectangle*, and the remaining are screen coordinates, all declared as of the class *integer*.

The implementation of CommonLoops is itself fully object-oriented in the sense that all data structures used to implement the system are objects that are instances of a class. So, for example, when a new method is defined, three new objects are created: the method object, the discriminator, and the discriminating function. The method object is the object that describes the method to be created, and the discriminating function is an object that selects the method that will be called. The discriminator and its own methods use the information in the method object and its own description of a generic function to compile the code for the method. *Generic function* is used here in the same sense as in the discussion of New Flavors.

Method Combination

Method combination is accomplished in CommonLoops using the run-super mechanism. It closely resembles the method combination approach used in Smalltalk, LOOPS, and ObjectLISP.

(LOOPS is an AI development tool used at Xerox PARC and will be described in detail in a subsequent column.) The run-super mechanism is implemented using the method and discriminator object described earlier. Because of the use of metaobjects in the implementation of method combination, many interesting research possibilities for AI languages are opened up. For example, through defining specialized method and discriminator objects, a means is available for integrating logic programming into CommonLoops. A prototype for such a system, called CommonLog, has been implemented at Xerox PARC. It is hoped that this will provide the basis for a more advanced AI tool called Vulcan. (This name was apparently not chosen by accident. One of the times I called the Intelligent Systems Lab at Xerox PARC, the entire staff was at the movie theatre to see the debut of *Star Trek IV*.)

Future Directions in Object-Oriented LISP

One of the issues still to be settled by the object-oriented LISP community and the object-oriented programming community in general is that of the structural vs. the procedural view of objects. This is the issue of whether the specification or interface description of classes should be purely procedural or split into procedural and structural parts. If purely procedural, an object is defined exclusively by its message protocols. As you have seen, CommonLoops is of the second type because method lookup is achieved by a combination of object structures and discrimination procedures. If things continue to proceed as they have been, it is anticipated that this approach will come to be adopted as the standard one.

On the whole, I don't think it is necessarily a problem of overwhelming difficulty to determine what would be the best kind of standard for the present as an object-oriented extension to Common LISP. Because it is a case of needing some standard now but not having enough experience with this area to fully define the possibilities, the only kind of standard that can at all serve is a partial standard based on those features of the technology that have shown themselves to be the most useful and reli-

able, while leaving the options as open as possible. To be more specific, I think that a new design for the standard needs to be constructed from the best features of CommonLoops, New Flavors, and ObjectLISP that address as many of the key issues I have been discussing as is feasible.

The main things from ObjectLISP that I feel should not be lost are the ability to modify objects and their variables on the fly and to keep instances and classes on an equal footing. One thing I would particularly like to see is a standard that did not prevent the option of having instantiated objects that were not yet formally members of any class but that at a later time could become "associated" with various classes and gain from what could be inherited from them. Another important issue from the AI perspective is allowing for the coexistence of multiple types of hierarchy in the same binding environment, where the same object can be a member of each of the different hierarchies simultaneously if this is so desired. As explained earlier, this feature appears essential for using objects to develop systems with deep models capable of reasoning about objects in real-world settings in terms of function, location, and generic significance.

In my next column I will continue the discussion of object-oriented programming in AI with a review of PC Scheme—an object-oriented programming system for IBM PCs and compatibles.

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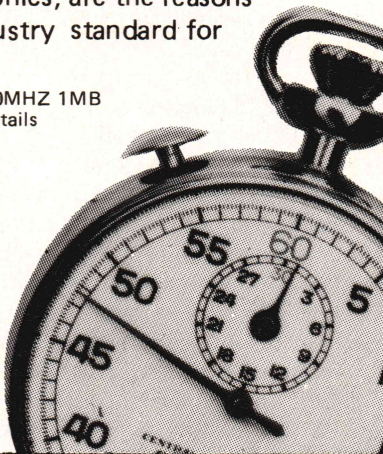
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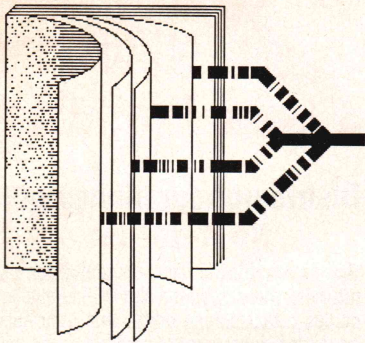
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The following exchange took place on the message board of DDJ FORUM, our SIG on CompuServe.

#: 7972 S9/UNIX for the PC

17-Nov-86 18:15:23

Sb: Dead Child Floating

Fm: Steve Sampson 75136,626

To: Multitasking expert

I've been trying to get a CRON program running on a Unix clone, but after each task finishes it leaves an entry in the process table—"terminated." Of course, this is unsightly, and I'd like to get it out. Is there a way to pop this without a `wait()` call? If it will help I can upload the offensive code. Maybe someone has seen this type of behavior before?

***There is a reply: 7986

#: 7986

Sb: Dead Child Floating

Fm: Fred Buck 73327,3604

Is your only beef that the `ps` command shows the process and says it's terminated? For how long a time does this condition continue? If stuff keeps clogging the process table, then that's bad news, but you say it's "unsightly," so I assume your objection is just to the cosmetic aspects. The `ps` command just takes a snapshot of the process table at the time you invoke it, and sometimes the dead stuff just hasn't been cleared out by that time. Do successive `ps` calls keep showing the same terminated process?

***There is a reply: 7995

#: 7995

Sb: Dead Child Floating

Fm: Steve Sampson 75136,626

Yes on the `ps`. I need to find out if the process entry ever goes away, but so far the terminated entry stays around for many minutes. This is just a cosmetic thing and more a question of programming. I'm still coming up to speed, and there's much to discover. I have found that when I kill CRON all the children drop out of the `ps` table.

***There is a reply: 8009

#: 8009

Sb: Dead Child Floating

Fm: Fred Buck 73327,3604

OK, I now believe I understand your situation. Let's see if I can summarize it correctly. You have a single, long-running process that spawns special-purpose children, each of which dies when its special purpose is finished. Such "dead" children show up in the process table as terminated as long as the long-running parent continues to run. You know that a `wait()` call will clear the entries out of the process table, but you don't want to paralyze your long-running parent by "waiting" for children. If I'm correct about what your problem is, I don't know any way other than a `wait()` call to do what you want to do, but on the other hand a `wait()` should be able to be broken by a signal, including an alarm signal. You should be able to clear out the dead children by placing, in some frequently traveled portion of the parent's code, something such as `alarm(1);` followed by `wait()`. Each time `wait()` is called, a dead kid will be stripped out of the process table (I assume you don't care about its exit status). If there're no dead kids but one or more alive kids, the `alarm()` will break out of `wait()` within one second. If there are no kids at all, `wait()` should return immediately. I'm assuming you've trapped the alarm signal appropriately. If I'm wrong about this, then just what is your objection to a `wait()` call?

Oops, `wait()` should be `wait(0);` or whatever variant of `wait()` that doesn't care about the child's exit status.

***There are replies: 8020, 8090

#: 8090

Sb: Dead Child Floating

Fm: Steve Sampson 75136,626

Well, I did state the problem in my nonverbose mode, but you summarized it very well. Thanks for the suggested work-arounds; I'll give them a try.

***There is a reply: 8101

#: 8101

Sb: Dead Child Floating

Fm: Fred Buck 73327,3604

I spoke to a friend tonight who has more Unix smarts than I do and can now provide the following additional details: the defunct child processes are more than just cosmetic, they in fact clog up the system process table and can (if sufficiently numerous) inhibit new process creation. In vanilla Unix there isn't really any way to handle such a situation other than the way I suggested or something very much like it. In some versions of Unix (perhaps standard in Berkeley—my friend wasn't off-top-of-head sure), there's a call called `wait3()`, which can be set to serve the single purpose of disposing of dead children and doesn't wait for a child to die if nothing but living children exist. The reason the dead children disappear when your CRON is killed is that child processes, upon the death of their parent, become adopted children of process 1 (`init`), which is almost always in a `wait()` and so takes care of them handily and which ignores deaths of children it doesn't remember having spawned itself.

***There is a reply: 8143

#: 8143

Sb: Dead Child Floating

Fm: Steve Sampson 75136,626

Good stuff here, Fred! Appreciate your help on this. I was thinking maybe there was a way to do it but was off on a very different tangent. The info on process 1 adopting children I suspected but didn't know how to get them adopted. Thanks.

#: 8020

Sb: #8009 Dead Child Floating

Fm: Levi Thomas (sysop) 76703,4060
 To: Fred Buck 73327,3604
 Why do these messages read like a Steven King novel? Dead kids? Paralyzed parents? Macabre metaphors, eh? Shall we start an on-line novel? A two-tiered story—on one level, a technical problem is stated and various solutions suggested. On another level is a horror story in the Edward Gorey style. Sorry, I get carried away sometimes—carry on.
 —Levi ("N is for Nevil who died of ennui") Thomas

***There are replies: 8027, 8054

#: 8027

Sb: Dead Child Floating
 Fm: Fred Buck 73327,3604
 Not to mention those instances in which a dead child prevents stuff from being flushed down a pipe. Especially if the child has been spawned by a demon.

***There is a reply: 8029

#: 8029

Sb: Dead Child Floating
 Fm: Duane Ellis 76064,1107
 If I did not know what you were talking about, you would get some very strange responses from me. As it is, a coworker came by and looked at my screen—I had to explain what is meant by dead children and flushing

them down pipes and also the fact that they could have a demon for a parent! Egads!

***There is a reply: 8044

#: 8044

Sb: Dead Child Floating
 Fm: Fred Buck 73327,3604
 Just imagine if Pat Robertson ever got a hold of this.

#: 8054

Sb: #8020 Dead Child Floating
 Fm: Neil J. Rubenking 72267,1531
 To: Levi Thomas (sysop) 76703,4060
 "S is for Sarah, who perished of fits; T is for Titus, who flew into bits."
 —Neil ("C is for Cora, who wasted away; D is for Desmond, thrown out of a sleigh; I is for Ina, who drowned in the lake; J is for Jake, who took lye, by mistake.") Rubenking

***There is a reply: 8064

#: 8064

Sb: Dead Child Floating
 Fm: Levi Thomas (sysop) 76703,4060
 Thanks for the Gorey details.
 <grin>

***There is a reply: 8076

#: 8076

Sb: Dead Child Floating
 Fm: jhon stanley 73765,1026

We called in an agent from M4 to investigate the dead children problem. His name was LEX. He lost his GREP on reality after spending a day YACcing with CAL, the supposed perpetrator. CAL gave him the month but not the DATE. "MORE," said LEX, "TALK, and MAKE my day." Then LEX used his pipe on CAL. He pulled CAL's FINGER out of its socket, which caused LEX's pipe to break.

LEX's partner walked in. He asked LEX to swap space because he had CAL's partner in the other room.

Lisa was a real looker. Her rap sheet was longer than—well, it was long. She was ready to confess. LEX was thinking of other things. Like, was the FTP florist still open?—Lisa needed some roses. "Inode what I was doin'. We took 'em down to the STREAM and let them float away. They was SLEEPing real peaceful. What's the DIFF? The superuser would a KILLED 'em when they EXITed anyway."

It was a dark and stormy night. . . .

DDJ

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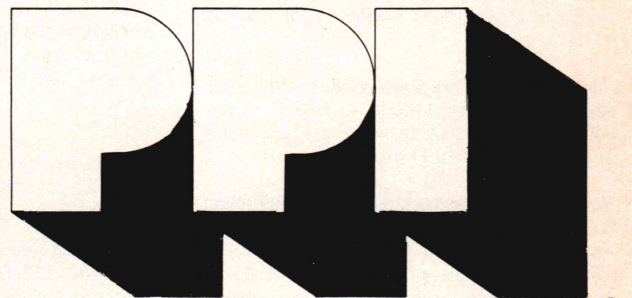
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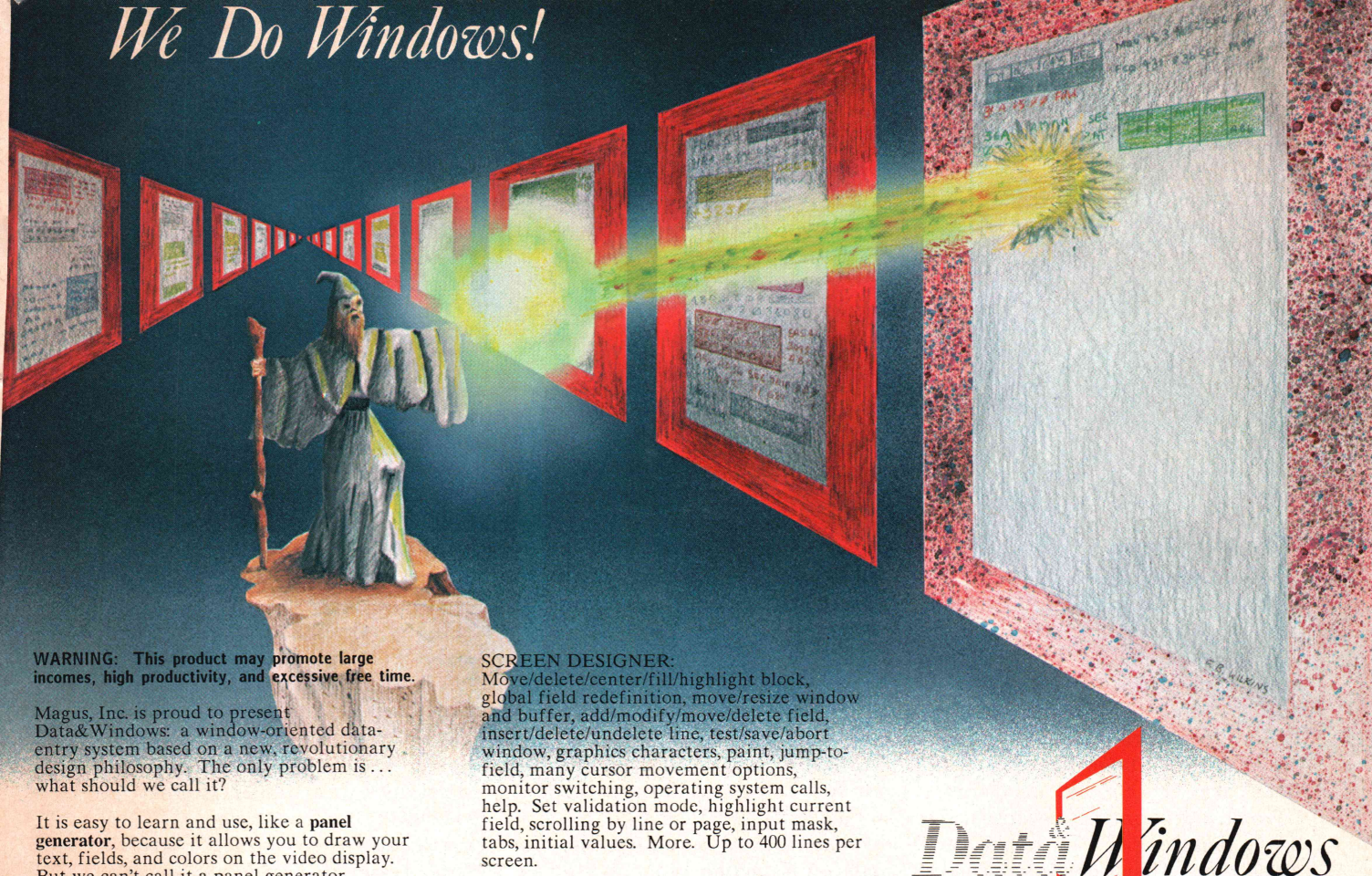
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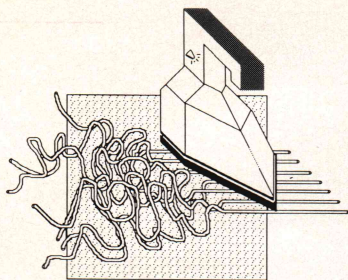
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THE STATE OF BASIC



The New Face of Subroutines

Those who learned BASIC with popular dialects such as Apple-soft BASIC, TRS-80 BASIC, MS-BASIC, and BASICA know how inefficient the `GOSUB <line number>` syntax is. First, the line numbers do not correspond obviously to the tasks that the subroutines carry out. Second, subroutines have no argument lists because these BASIC dialects support global variables only. These conditions make the readability of BASIC programs, especially those lacking numerous comments, difficult. The good news is that the "new wave" BASICs effectively handle these problems. In this issue I will discuss the way in which subroutines are implemented in QuickBASIC and True BASIC, taking advantage of their similar implementations. In the next column, I will look at BetterBASIC's subroutines, which are more like those of Pascal.

The subroutines in QuickBASIC reflect Microsoft's response to the need for more sophisticated syntax. The solution QuickBASIC offers is twofold. First, alphanumeric labels replace line numbers. Thus, you can rewrite an ambiguous `GOSUB 2000` in the old BASIC as `GOSUB READ.FILE`. The label `READ.FILE` says much more than a line number of 2000!

The second boost to subroutines in QuickBASIC is the implementation of named subroutines that have an optional argument list, much like those in FORTRAN. QuickBASIC supports a strict data interface: all variables used by the subroutine that do not appear in the argument list are local, even if they have identical names to those of variables in the main pro-

gram. Example 1 (below) shows two simple subroutines: the first clears a screen line, and the other centers text on a specified line number. Subroutine *Center.Text* calls subroutine *ClrLine* and passes the line number specified. The *STATIC* declaration is mandatory and also serves as a reminder that recursive subroutines are not yet implemented.

QuickBASIC subroutine parameters are passed by reference when a variable is used and by value when an expression is used. To protect a scalar variable from being altered by a subroutine, enclose it in parentheses to make it an expression (see commented `CALL ClrLine` in Example 1).

Passing arrays is also simple. QuickBASIC needs to know the number of dimensions the array has when you declare the subroutine. Example 2, page 157, shows a subroutine that calculates the average and standard deviation values of a specified column in a numeric table. The matrix *X* is written as *X(2)* to indicate that it's two-dimensional. QuickBASIC provides the *LBound* and *UBound* functions to return the array's lower and upper bounds, respectively. For one-dimensional arrays you simply enclose the array name in either function to obtain the sought bounds. In the case of multidimensional arrays, a second argument is needed—namely, the dimension number. In Example 2, the `FOR...NEXT` loop iterates for all rows in matrix *X*. Assuming that the rows of the numeric matrix are represented by the first dimension and the columns by the second, I use `LBound(X,1)` and

`UBound(X,1)` to obtain the row limits. The array-bound functions are very powerful for helping you write general-purpose routines that manipulate arrays of any size.

QuickBASIC also provides the *SHARED* attribute, used with *COMMON*, *DIM*, and *REDIM* statements, to shorten argument lists of subroutines. The *SHARED* attribute declares the variables and arrays as global and accessible to all routines within a single program. Thus, you should only declare variables that are logically global (that is, needed by most routines) as *SHARED* to avoid the side effects of the old BASICs.

Finally, QuickBASIC subroutines can be exited from using the `END SUB` statement. Subroutines cannot be nested among themselves or with function definitions.

True BASIC implements named subroutines in a similar manner to QuickBASIC. True BASIC does not support labels, so the `GOSUB <label>` syntax is not available—just the `GOSUB <line number>` (if line numbers are used at all). The preceding discussion of QuickBASIC subroutines applies to True BASIC, with the following exceptions:

- True BASIC supports recursive calls.
- The syntax for declaring arrays in the subroutine argument lists is slightly different. True BASIC requires a comma for each additional dimension. Thus, a simple array *X* is declared as *X()*, whereas a matrix *X* is written as *X(,)*, and so on. With the advent of True BASIC Version 2, called subroutines passing array arguments

```
SUB ClrLine(Line.Num) STATIC
  LOCATE Line.Num,1
  PRINT STRING$(80, " "); ' clear line
END SUB

SUB Center.Text(T$, Line.Num) STATIC
' Subroutine to center a text
CALL ClrLine(Line.Num) ' pass Line.Num by reference
' or
' CALL ClrLine( (Line.Num) ) to pass Line.Num by value
LOCATE Line.Num, (40 - LEN(T$)/2)
PRINT T$
END SUB
```

Example 1: QuickBASIC subroutines to clear a line and center a text on the screen

can optionally (for enhanced readability) include parentheses, following exactly the same rules as subroutine declarations do.

- True BASIC supports both internal and external subroutines. Internal subroutines are declared within the main BASIC program and before the unique *END* statement. External subroutines can reside in external libraries, modules, or beyond the *END* statement. The difference between the subroutine types is their accessibility to variables in the main program. The main program (up to the *END* statement) is regarded as one programming unit within which all variables are accessible. Thus, internal subroutines can also create and manipulate global variables not appearing in the argument list. Unlike QuickBASIC subroutines, internal True BASIC subroutines have no local variables. This is an important difference to remember if you ever translate programs between the two implementations. External subroutines do not enjoy the same privilege and thus have a stricter data interface, similar to that in QuickBASIC. Examples 3 and 4 (right) show the True BASIC versions of Examples 1 and 2, respectively.

Looking at the subroutines in the new wave BASICs, you can see a touch of FORTRAN present, and why not? They offer a radical solution to a chronic problem that plagued the old microcomputer BASICs. Callable subroutines are also endorsed by Borland International in its new Turbo BASIC. At the time of writing this column, I have Borland's Comdex Fall-86 press release, which indicates that Turbo BASIC will have the more powerful subroutine syntax. Perhaps the Beatles' lyrics from a song on the Sgt. Pepper album provide a suitable comment on BASIC — "It's getting better all the time!"



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```
DEF FNMissing = -1E+30 ' define numeric code for missing numbers
SUB Get.Stat(X(2), Col%, Average, StdDev) STATIC
' Get average and std. deviation of column Col% of
' two-dimensional array X(,)

Sum = 0
SumX = 0
SumXX = 0

FOR Row% = LBound(X,1) TO UBound(X,1)
  IF X(Row%,Col%) > FNMissing THEN ' Valid data?
    Sum = Sum + 1
    SumX = SumX + X(Row%,Col%)
    SumXX = SumXX + X(Row%,Col%)^2
  END IF
NEXT I

Average = SumX / Sum
StdDev = SQR((SumXX - SumX^2/Sum) / (Sum - 1))

END SUB
```

Example 2: QuickBASIC subroutine to obtain the average and standard deviation of data stored in an array

```
SUB ClrLine(Line_Num)
SET CURSOR 1,Line_Num
PRINT REPEAT$(" ",80); ! clear line
END SUB

SUB Center_Text(T$, Line_Num)
! Subroutine to center a text
CALL ClrLine(Line_Num) ! pass Line_Num by reference
! or
! CALL ClrLine( (Line_Num) ) to pass Line_Num by value
SET CURSOR (40 - LEN(T$)/2),Line_Num
PRINT T$
END SUB
```

Example 3: True BASIC subroutines to clear a line and center a text on the screen

```
DEF Missing = -1E+30 ! define numeric code for missing numbers
SUB Get_Stat(X(,), Col, Average, StdDev)
! Get average and std. deviation of column Col of
! two-dimensional array X(,)

LET Sum = 0
LET SumX = 0
LET SumXX = 0

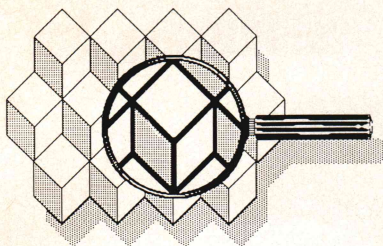
FOR Row = LBound(X,1) TO UBound(X,1)
  IF X(Row,Col) > Missing THEN ! Valid data?
    LET Sum = Sum + 1
    LET SumX = SumX + X(Row,Col)
    LET SumXX = SumXX + X(Row,Col)^2
  END IF
NEXT I

LET Average = SumX / Sum
LET StdDev = SQR((SumXX - SumX^2/Sum) / (Sum - 1))

END SUB
```

Example 4: True BASIC subroutine to obtain the average and standard deviation of data stored in an array

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Discovery Systems has released an audio-cassette training program for Autodesk's AutoLISP, a training course for AutoCAD users. The eight lessons provide a step-by-step program with complete instructions to create custom AutoLISP functions, custom menus, and other time-saving utilities. The price is \$179. Reader Service No. 26.

Discovery Systems
34 Autumnleaf
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DDJ

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SWAINE'S FLAMES

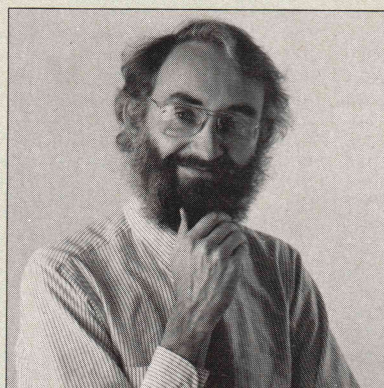
■ Mattel and Axlon have been granted permission by the FCC to broadcast robotic control signals to Mattel and Axlon toys as part of a new departure in children's television programming. The toys will move in response to events on screen and shoot at targets on the screen. This scheme is being touted as "interactive," which is nonsense.

There is an interesting precedent for such "interactive" television, and it seems to include all the elements of the present case but one. The precedent had special products that allowed a similar level of "interaction" with the television program; it created two classes of viewers—those who had the products and those who didn't; and it was initially perceived as a departure in children's television programming. What it did not have was an individualized signal sent out over the public airways.

The precedent I have in mind was a cartoon series called "Winky Dink and You" from the days of black-and-white television. If you sent for a special plastic sheet to place over your television screen and special crayons for drawing on it, you could customize W. Dink's on-screen adventures. I don't recall that the producers were accused of economic discrimination, but those were black-and-white times.

Subtract Winky Dink from the Mattel/Axlon scenario and you are left with the individualized television signal and the question of the appropriate use of a limited information channel. I suspect that any effective protest of the plan will focus on that signal. I also suspect that this skirmish, like the Captain Video airwave hijacking of last year, presages an increasing number of battles for bandwidth. ■

There has been some discussion in our pages and in some more archly academic journals of the failings of



conventional implementations of PROLOG as a tool for logic programming. One writer who has not only criticised but suggested ways to bring PROLOG closer to the ideal of logic programming is Lee Naish, who addresses PROLOG's knottiest problems in his book *Negation and Control in Prolog* (Berlin/Heidelberg: Springer-Verlag, 1986).

All PROLOG implementations have some problem with negation. PROLOG is based on Horn-clause logic, and negative information cannot really be expressed in Horn-clause form. PROLOG implementations typically treat negation by more or less identifying it with failure: letting x cannot be proved stand for x is false. This is often a perfectly reasonable thing to do, but if implemented naively it can lead to illogical conclusions. Naish lays out recommendations for the effective implementation of negation. PROLOG vendors should read them.

The problem with control in PROLOG programs is that semantically innocuous variations in the control logic can cause huge changes in performance. Naish contends that the heuristics of good PROLOG coding that programmers have developed to deal with this problem are by and large simple, effective, and automatable. His approach is to let a preprocessor restructure the code to avoid the worst of the inefficiencies. PROLOG programmers should read this part.

My cousin Corbett has recently been combining catastrophe theory with market analysis and producing

surprising results. Catastrophe theory is the fledgling discipline that studies systems on the brink, where the fundamental assumptions on which the study of the systems is built cease to apply.

His inspiration was an article on parallel computers in *High Technology* magazine. Having approached the article to learn about the parallel-computer market, he was nonplussed to find that there was no such thing: that there are degrees of parallelism; that different architectures serve different purposes; that the parallel machines do not compete in one market but define several overlapping, interdependent market fragments.

Expanding his research, Corbett found other computer industry markets in catastrophic transition. The 80386 computer market, with its prenatal cloning, spectre of proprietary designs, and its nonexistent software, has been a particularly fruitful object of study. Then there's the C compiler market, clearly catastrophic, through which Corbett discerns a major fault line developing with optimization on one side and convenience on the other. When the big split comes, Corbett says, half the C market will fall away into ease of use.

The night before it happens, farm animals will be restless.

Oh, yes. If I remember correctly, the Winky Dink television program went away in the face of parental protest. Apparently the producers had not reckoned with the resourcefulness of American youth, who quickly discerned that there was no need to send for the special plastic sheet or the special crayons. You could just draw on the glass with your Crayolas.

Michael Swaine

Michael Swaine
editor-in-chief

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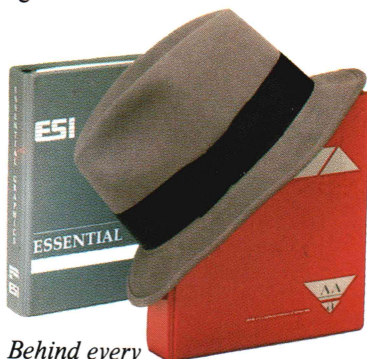
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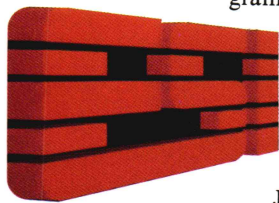
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*Introductory price—good through July 1, 1987

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- ✓ **Compiler:** One-pass compiler generating linkable object modules and inline assembler. Included is Borland's high performance "Turbo Linker." The object module is compatible with the PC-DOS linker. Supports tiny, small, compact, medium, large, and huge memory model libraries. Can mix models with near and far pointers. Includes floating point emulator (utilizes 8087/80287 if installed).
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Sieve benchmark (25 iterations)

	Turbo C	Microsoft® C	Lattice C
Compile time	3.89	16.37	13.90
Compile and link time	9.94	29.06	27.79
Execution time	5.77	9.51	13.79
Object code size	274	297	301
Price	\$99.95	\$450.00	\$500.00

Benchmark run on a 6 Mhz IBM AT using Turbo C version 1.0 and the Turbo Linker version 1.0; Microsoft C version 4.0 and the MS overlay linker version 3.51; Lattice C version 3.1 and the MS object linker version 3.05.



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